The Journal of Bone and Joint Surgery

The Official Publication of
The American Orthopaedic Association
The British Orthopaedic Association
The American Academy of Orthopaedic Surgeons
The Australian Orthopaedic Association
The Canadian Orthopaedic Association
American Society for Surgery of the Hand
New Zealand Orthopaedic Association
South African Orthopaedic Association

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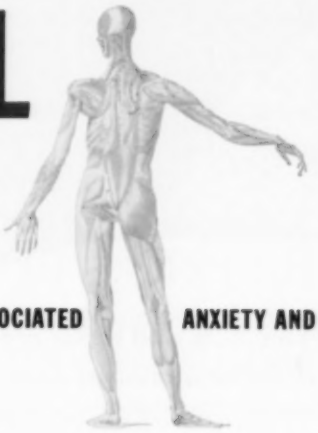

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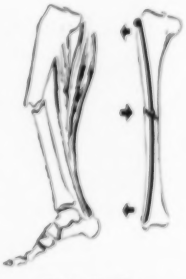

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* Rush, Leslie V.: Fracture Problems, Mississippi Doctor, Vol. 36, No. 5.115–118, Oct., 1958.

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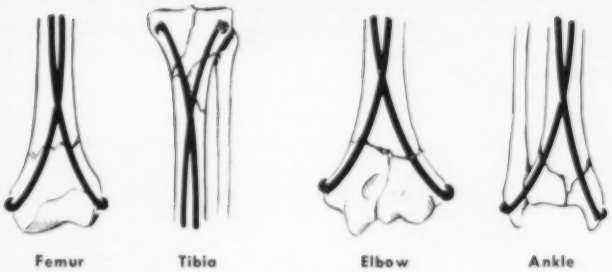

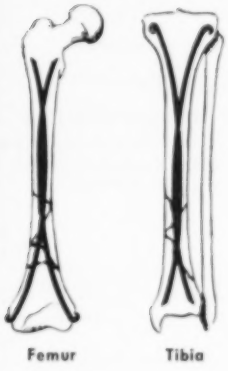

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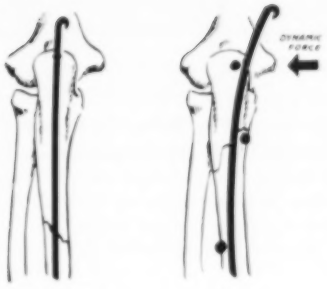

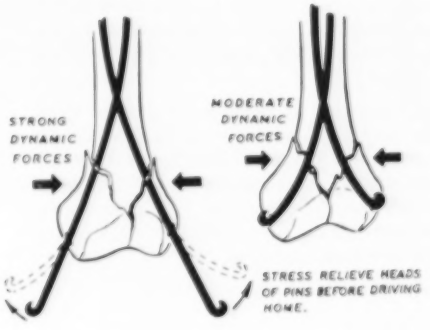

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2.

LATER POSTMENOPAUSE

Back pain is severe, spreading to hips ("girdle pain")

Patient is round shouldered, walks with a stoop

X-ray reveals compression fractures of lower vertebrae

3.

70 AND OVER

Fracture of hip after a minor fall

X-ray reveals fracture of neck of femur

X-ray reveals compression fractures of lower lumbar vertebrae

These three patients have osteoporosis. Early diagnosis and treatment with "Formatrix" is important because osteoporosis is probably the only age change that can be averted. With "Formatrix" therapy, relief from the symptoms of *low back pain, vague aches* and *fatigue* may be obtained in as little as a few weeks. "Formatrix" supplies the essential materials to stimulate increased bone formation and prevent further loss of bone substance that leads eventually to loss of height, stooped posture, and disabling fractures.

The highest incidence of osteoporosis may be found among the 14,000,000 women in the U.S.A. who are 55 years of age and over. Some investigators claim that almost all women past the menopause will show some degree of osteoporosis; furthermore, if all these women were examined carefully, 50 per cent would show x-ray evidence of decreased bone mass.

Suspicion may be the handiest diagnostic tool since presenting symptoms vary from mild to severe and incapacitating pain, and no x-ray evidence of spinal degeneration is available until about 30 per cent of the bone matrix is lost. Between these two extremes there are other signs of estrogen deficiency such as *wrinkled and thinning skin, a tendency to appear older than stated years;* there may also be *hypercalciuria* when postmenopausal osteoporosis is complicated by acute osteoporosis of disuse.

Osteoporosis is primarily an atrophic condition of bone matrix formation and any factor that depresses osteoblastic activity or retards the formation of protein and connective tissue such as *prolonged immobilization, cortisone therapy,* or *malnutrition* will favor development of osteoporosis in both male and female.

5978

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NEW

In answering advertisements, please mention *The Journal of Bone and Joint Surgery*

"FORMATRIX" contains three most essential bone building materials necessary *for matrix* formation, estrogen, androgen and vitamin C.

The estrogen component of "Formatrix" stimulates osteoblastic activity, thus aiding calcium and phosphorus deposition; it also imparts a feeling of "well-being." The anabolic action of methyltestosterone promotes the synthesis of protein and restores a positive nitrogen balance. Together, these hormones have a greater effect on bone and protein metabolism than either alone, and side effects are minimized because of the opposing action of the two steroids on sex-linked tissues. Vitamin C plays an important role in formation of intercellular cement substance and amino acid synthesis. "Formatrix" has a large amount of vitamin C to aid in new bone matrix formation and to further help in the healing of fractures.

"FORMATRIX" – each tablet contains:

Conjugated estrogens equine ("Premarin"®)	1.25 mg.
Methyltestosterone	10.0 mg.
Ascorbic acid	400.0 mg.

Dosage: 1 tablet a day – In the female, three weeks of treatment with a rest period of one week between courses is recommended.

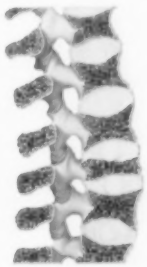
Supplied: Tablets, bottles of 60 and 500.

LITERATURE AVAILABLE ON REQUEST

1.

EARLY POSTMENOPAUSE
No x-ray evidence of bone lesion

2.



LATER POSTMENOPAUSE
X-ray reveals compression fracture of lower vertebrae

3.

70 AND OVER
X-ray reveals fracture of neck of femur

TO RELIEVE LOW BACK PAIN – TO PROMOTE HEALING OF FRACTURES

in osteoporosis

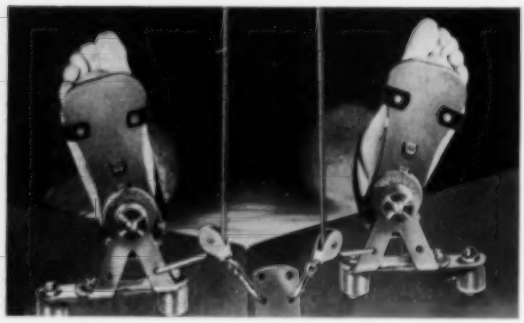
"FORMĀTRIX"

(Brand of Steroid – Vitamin Combination)

for matrix formation

In answering advertisements, please mention *The Journal of Bone and Joint Surgery*

BOWEN FRACTURE APPLIANCES— GREAT AIDS TO BETTER SURGERY



LEG EXERCISER SETS

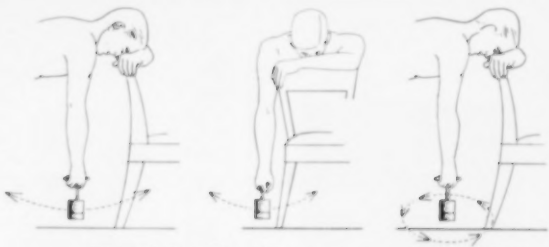
Designed to assist in passive abduction after cup arthroplasty, rehabilitation of paraplegics, and many other cases requiring weight controlled exercises.

- **Rigid Construction—Relatively Light in Weight**
- **Moves Freely on Ball Bearings in All Directions**
- **Protractor Adjustment for Foot Angle Control**
- **Weight Attaching Eyes at Different Levels**
- **Foot and Heel of Exerciser Covered with Foam Rubber**
- **Exercising Board 14" x 48", Hinged at Center and Angled to Approximate the Arc Scribed by the Legs**

ORMANDY PENDULUM EXERCISER

To Prevent Frozen Shoulder

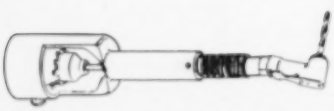
An excellent means to RELIEVE MUSCLE SPASM and PAIN of the shoulder girdle by traction in order to increase the ARC OF MOTION of the scapulo-humeral joint.



Efficient Method of Exercising for Shoulder—Joint Injuries

To Prevent Frozen Shoulder

The compact size of the Pendulum Exerciser will make it possible to increase the arc of motion without hitting the leg of the patient.



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For Luck Bone Saw and Stryker Drill

Designed Especially for the Benkhart Operation

Excellent for bone surgery at difficult angles and in restricted areas requiring use of drills, curetting burrs, slotting burrs. Rigidly constructed, light in weight. Entire unit may be sterilized. Two 1/12 inch diameter High Speed Drills supplied with each attachment.

Easily attached to Jacobs chuck with key.

A hole in the end of the drill bit is provided so that the suture can be threaded and pulled through with the extraction of the drill.

GONIOMETER— Pocket Size Anodized Aluminum

A Pocket Size instrument with calculation flexibility allowing complete angle determination in degrees.

Produced from aluminum, anodized and dyed black, with white-lead-filled dial and indications permitting full penetration of radiation and screening a permanent secondary shadow of measurement on the film for consultations and computations.

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"It is axiomatic that prosthetic material for use within the body must be inert."[1]

The totality of clinical inertness

"...the surgeon should know as much about the material he puts into his patients as he does about the disease he is treating."[2]

Recently, Burch cogently summarized the criteria for metal appliances; he considers it most desirable that the appliance "be electrically neutral and entirely passive in the presence of body fluids, and sufficiently rigid and strong to do its part mechanically. It should retain its molecular veil of passivity in the presence of agitation and friction, and remain completely passive *in vivo*."[2]

ELECTRIC NEUTRALITY – In a discussion of metals in orthopedic surgery, McKee[3] emphasizes that even polishing or machining, as used in the production of stainless steel appliances, creates an electric potential, thus initiating a corrosive process. Such processes can also be triggered by damaging the investive oxide film and by mechanical stresses.[1-9]

VITA

in 1947 it was stated:

"Vitallium appliances can be left in the body indefinitely for ... there is no damage to tissues, and there is no disintegration or solution of the metal in body fluid. As a result, appliances of Vitallium become embedded in bone and soft tissue with a minimum of scar tissue formation."[9]

References:

1. McKeever, D. C.: Clin. Orthop., No. 6, p. 17, 1955. 2. Burch, J. E.: Southern M. J. *51*:1390, Nov. 1958. 3. McKee, G. K.: Lancet *1*:1174, June 8, 1957. 4. Wright, J. K. and Axon, H. J.: J. Bone & Joint Surg. *38*B:745, Aug. 1956. 5. Scales, J. T. and Zarek, J. M.: J. Bone & Joint Surg. *37*B:5
Nov. 1955. 6. Callahan, J. J.: S. Clin. No
America, W. B. Saunders Co., Philadelphia, P
1957, p. 135. 7. Curry, G. J. and Pine, D. K.: A
J. Surg. *95*:518, Apr. 1958. 8. Scales, J. T.: J. Bo

BODY FLUIDS AND METAL – As shown by Gross and Gold,[10] Vitallium implants – either cast or wrought – "were compatible with the soft tissues and bone and did not cause any observable clinical or histologic injury." Similar observations were made by Secord and Breck,[11] Smyth,[12] Venable and Stuck,[9] Wright and Axon[4] and others.[5,8] It was demonstrated[4] that plasma and normal saline not only affect stainless steel per se, but also accelerate electrolytic processes and corrosion. This "electrolytic inflammation" interferes with healing, and the tissue reaction or "chemical abscess," "may point through the skin and become secondarily infected." When using stainless steel, they frequently obtained "primary skin healing of the plated fracture without any evidence of sepsis, but with localized wound breakdown six or eight weeks later."[4]

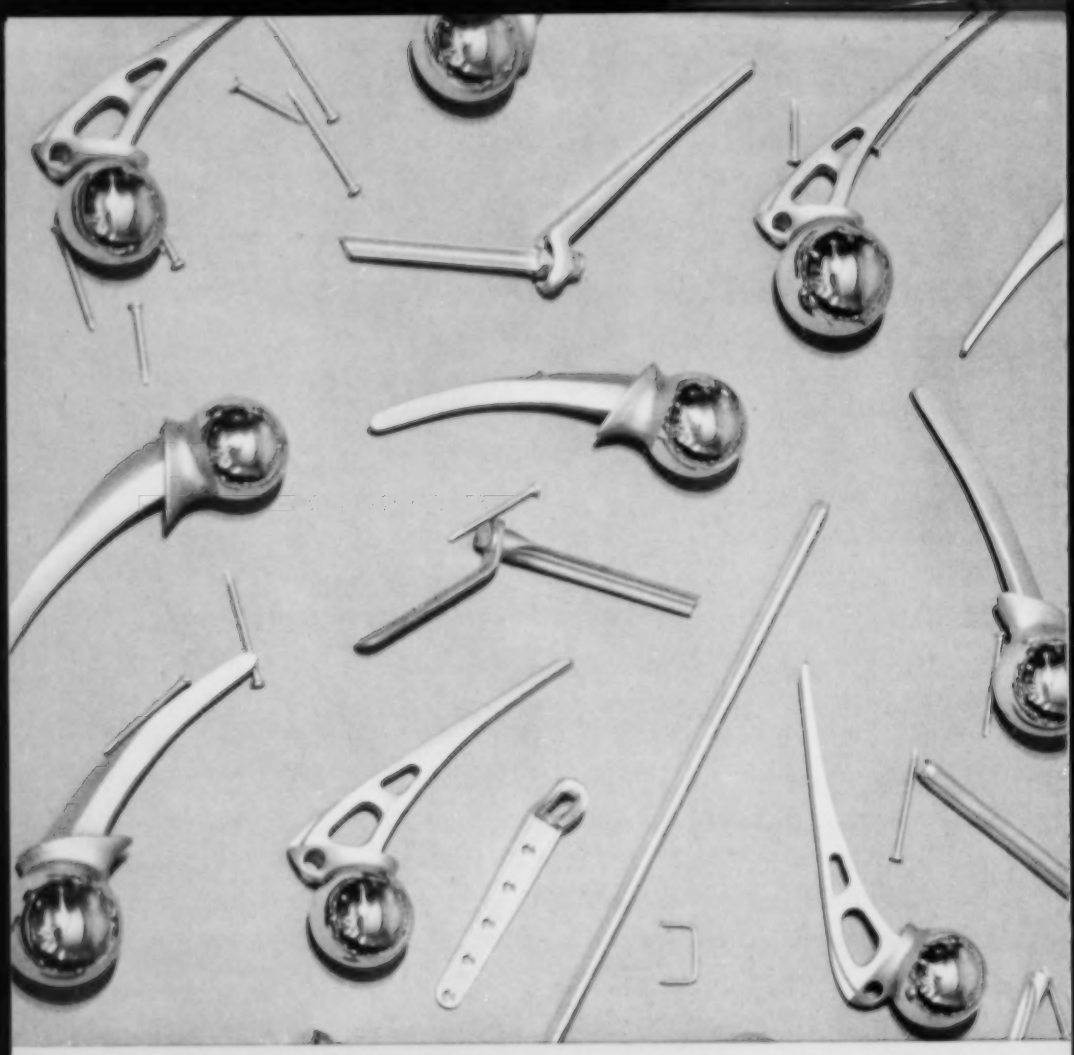
MECHANICAL STRENGTH – Day and Hinchey[13] report "no instances of fracture of the [Moore] prosthesis" and Scales and Zarek[5] "have never seen a cobalt-chrome implant which has failed either mechanically or biologically because of corrosion phenomena." They "believe that the cobalt-chrome alloys have in clinical experience proved to be so superior in all respects to the existing stainless steels that they should now be very seriously considered for all surgical implants."[5]

LLIUM

In 1957 it was reported:

"There is general agreement that Vitallium is the least physiologically disturbing [metal] to tissues . . . [Its] unique suitability for surgical appliances derives from its inherent corrosive resistance, its compatibility with human tissues, its inertness and lack of electrolytic activity, together with its toughness and strength."[6]

Joint Surg. *38*B:754, Aug. 1956. **9.** Venable, S. and Stuck, W. G.: Internal Fixation of Fractures, Charles C. Thomas, Springfield, 1947, pp. -52, 63. **10.** Gross, P. P. and Gold, L.: Oral Surg. :769, July 1957. **11.** Secord, E. W. and Breck, L. W.: J. Bone & Joint Surg. 22A:749, July 1940. **12.** Smyth, E. H. J.: J. Bone & Joint Surg. *40*B:778, Nov. 1958. **13.** Day, P. L. and Hinchey, J. J.: Clin. Orthop. No. 6, p. 27, 1955.



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acceptance by surgeons is attested to by
the fact that over 7,500,000 Vitallium appliances
were used in the last 23 years...

...that is over 900 daily!
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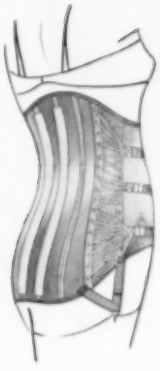

MODEL 423
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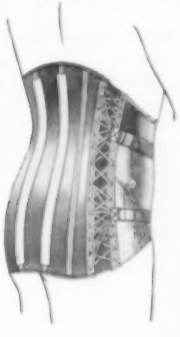
Support for Women



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There's a quality Freeman support for most every application. You can be certain that the garment you select will carry out your prescription to the best possible satisfaction of you and your patient.

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New Dacron-Pima Cotton Fabric. Petal-Soft Interior Finish cushions the stays, avoids irritation. Self-Smoothing, Exclusive Non-Wrinkle Fly speeds putting on garment and avoids comfort-robbing wrinkles. Soft Plush Padding under hooks and eyes. Superb Needle Work.

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Please send details on new Freeman features and include free reference catalog.

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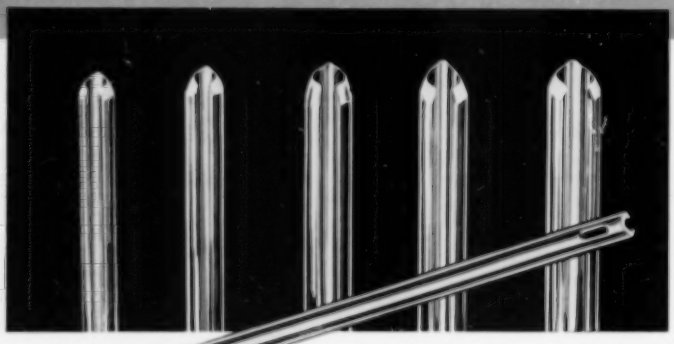
Rely on original Küntscher

CLOVERLEAF medullary NAILS

by Orthopedic



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SIZES:

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Kenacort safely starts your patients off right — with all the benefits of systemic corticosteroid therapy and few side effects to worry about. Increased corticoid activity is provided on a low dosage schedule[1-3] without edema,[1-4] psychic stimulation,[1-3] or adverse effect on blood pressure.[1-3,5] A low sodium diet is not necessary.[4,5] Gastrointestinal disturbances are negligible[2,4,5] with less chance of peptic ulcer.[4] This makes Kenacort particularly valuable in treating your "problem patients" — such as the obese or hypertensive and the emotionally disturbed.

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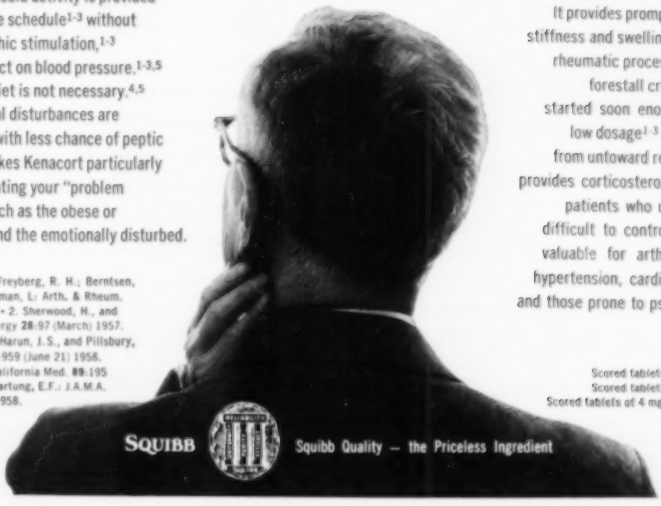
Kenacort, particularly in the treatment of your arthritic patients, has proved effective where other steroids have failed. It provides prompt, safe relief of pain, stiffness and swelling by suppressing the rheumatic process[1-5] — and may even forestall crippling deformities if started soon enough. Because of its low dosage[1-3] and relative freedom from untoward reactions,[1-5] Kenacort provides corticosteroid benefits to many patients who until now have been difficult to control. It is particularly valuable for arthritic patients with hypertension, cardiac disease, obesity and those prone to psychic disturbances.



SUPPLIED:
Scored tablets of 1 mg. — Bottles of 50
Scored tablets of 2 mg. — Bottles of 50
Scored tablets of 4 mg. — Bottles of 30 and 100

REFERENCES: • 1. Freyberg, R. H.; Berntsen, C. A., Jr., and Hellman, L.: Arth. & Rheum. 1:215 (June) 1958. • 2. Sherwood, H., and Cooke, R. A.: J. Allergy 28:97 (March) 1957. • 3. Shelley, W. B.; Harun, J. S., and Pillsbury, D. M.: J.A.M.A. 167:959 (June 21) 1958. • 4. Dubois, E.L.: California Med. 89:195 (Sept.) 1958. • 5. Hartung, E.F.: J.A.M.A. 167:973 (June 21) 1958.

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Price including table 28 x 30 x 32

Model # 9952 $159.50

Price without table with bracket for attaching to plinth,

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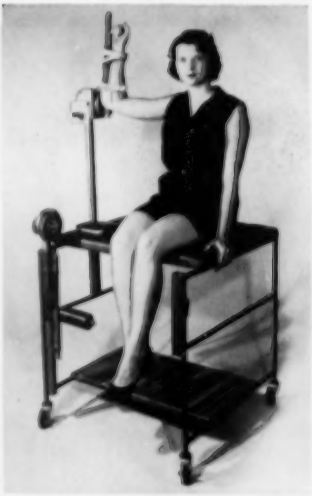
Showing Resistance Control Calibration in pounds. →



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better tolerated and safer than older drugs

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References: 1. Cooperative Study, Department of Medical Research, Winthrop Laboratories • 2. Lichtman, A. L.: Kentucky Acad. Gen. Pract. J. 4:28, Oct., 1958 • 3. Baker, A. B.: Modern Med. 26:140, April 15, 1958.

***tran-qui-lax-ant** [< L. *tranquillus*, quiet; L. *laxare*, to loosen, as the muscles]

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Trancopal (brand of chlormethazanone) and Caplets, trademarks reg. U.S. Pat. Off.

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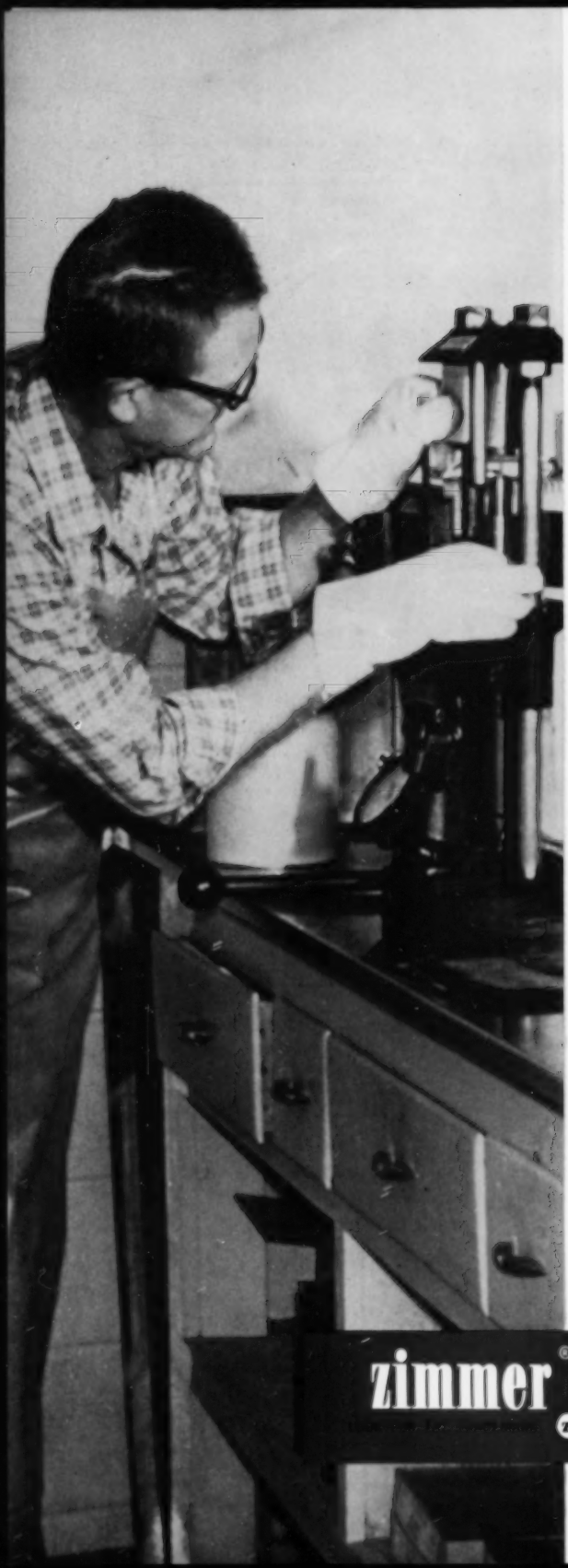

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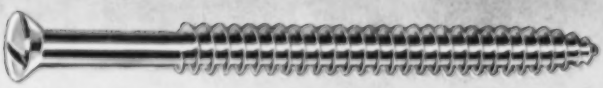
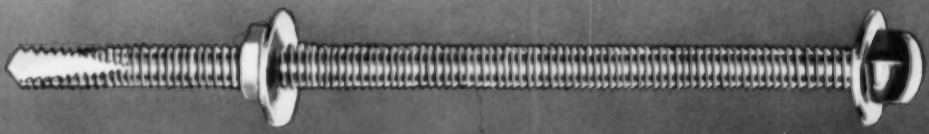


HIP SCREW NO. 259

MODIFIED HAGIE PIN NO. 516

KNOWLES PIN NO. 281-A



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PARAFON* with PREDNISOLONE

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PARAFON relieves pain, stiffness, and disability caused by rheumatism and traumatic disorders; PARAFON WITH PREDNISOLONE compounds this relief with anti-inflammatory action in treatment for arthritis.

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precautions: The precautions and contraindications that apply to all steroids should be kept in mind when prescribing PARAFON WITH PREDNISOLONE.

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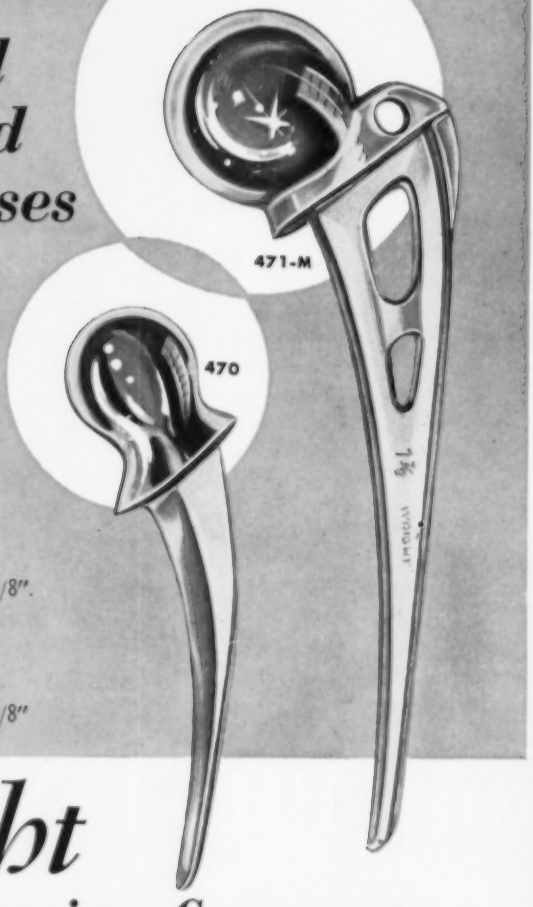

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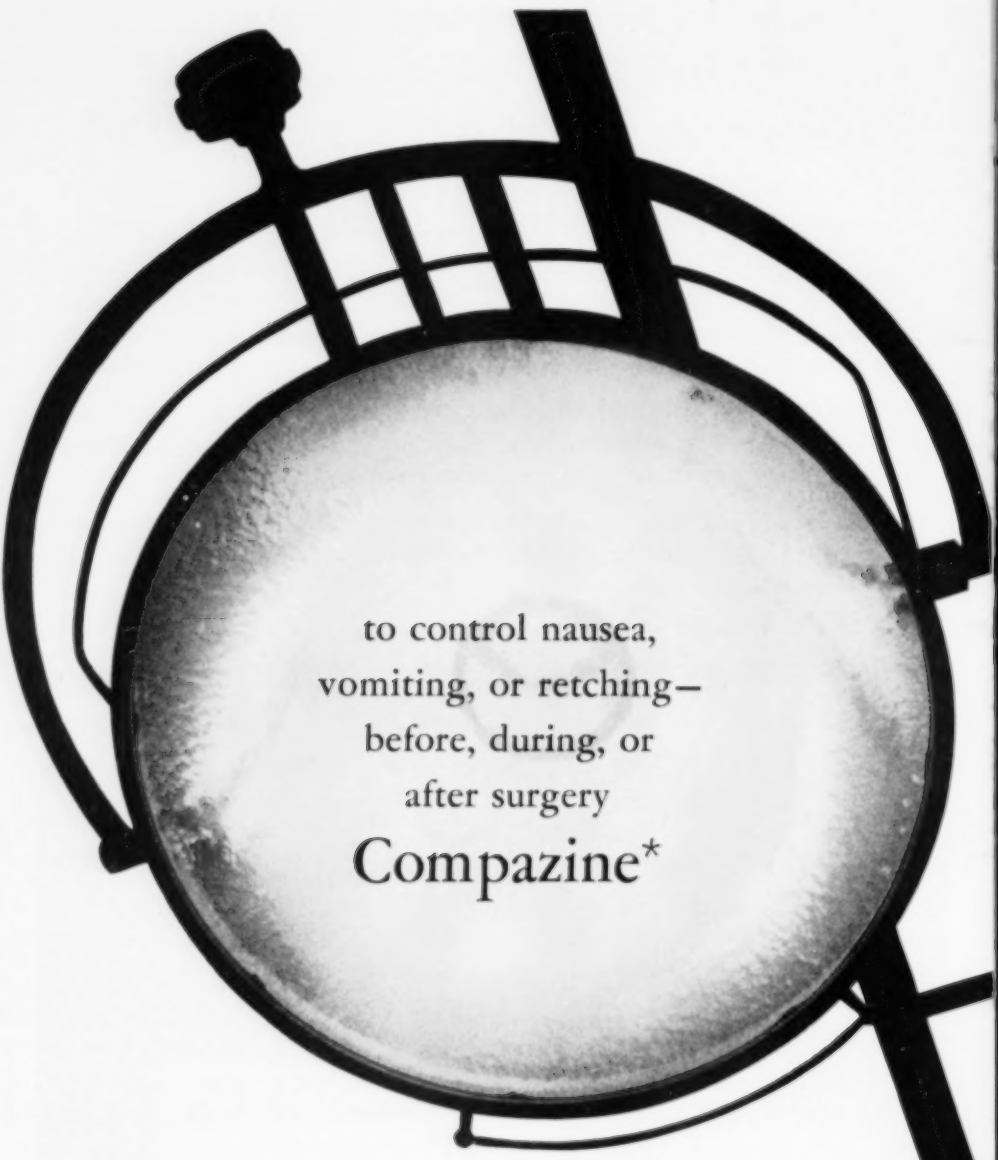

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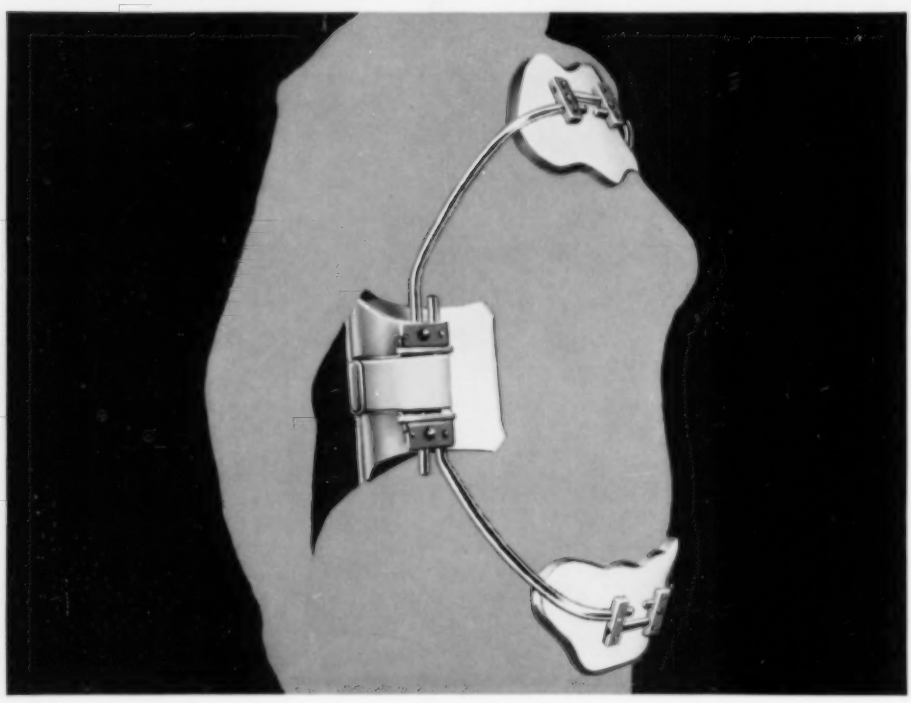

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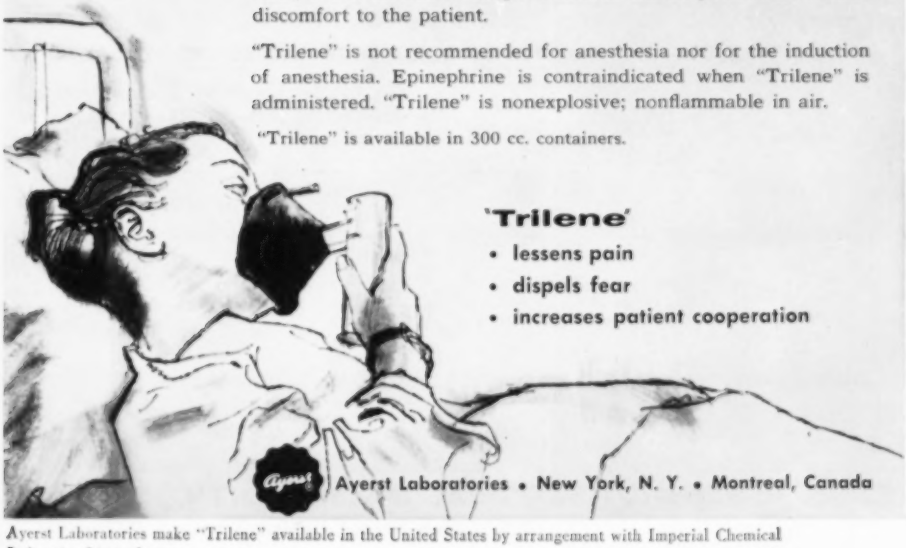

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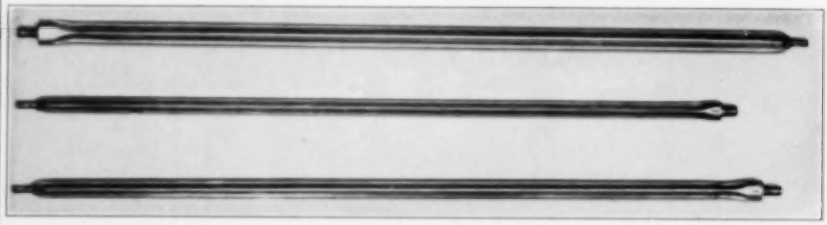

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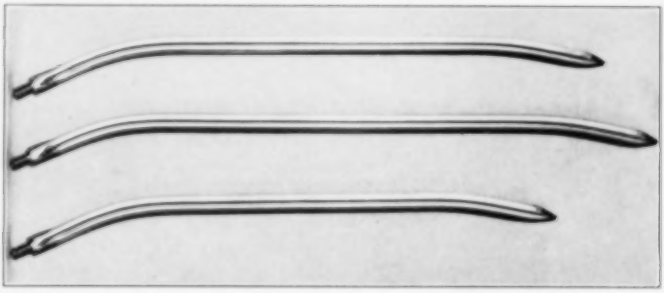

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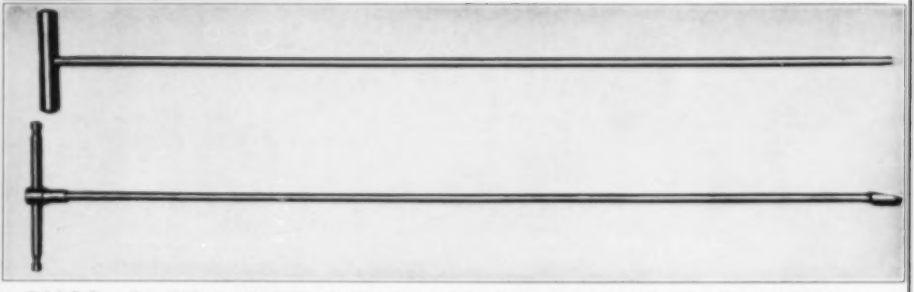

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The Journal of
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The Phasic Activity of the Muscles of the Lower Extremity and the Effect of Tendon Transfer*

BY J. R. CLOSE, M.D., AND F. N. TODD, OAKLAND, CALIFORNIA

From the Department of Orthopaedic Surgery, Highland-Alameda County Hospital, Oakland

The rhythmic, intermittent contractions of the muscles of the lower extremity during walking may be conveniently associated with the events of the walking cycle. If continuous oscillograms are recorded from individual muscles and plotted according to their occurrence during the stance and swing phases of the walking cycle, a display of the phasic activity of the various muscles results[6,8]. Patterns of electrical activity exhibited by the muscles of the lower extremity are found to be quite consistent. As the subject walks, the intermittent contraction of each muscle is readily identified with its phase. Thus, in the normal subject, the anterior muscles of the leg are predominantly swing-phase muscles. The posterior or flexor muscles are stance-phase muscles. In the thigh, the quadriceps is characteristically a stance-phase muscle, while the hamstring muscles are basically of the swing-phase type. Examples of the oscillograms taken from the muscles of the normal leg and thigh are shown in Figures 3 and 4.

Phasic activity was studied for many years by Scherb, who used the method of manual palpation, with the subject walking on a treadmill. Averages from hundreds of patients were compiled. Scherb later checked the manual method with electronic methods. Apparently only a few normal superficial muscles—the glutaeus medius, glutaeus maximus, sartorius, biceps femoris, semitendinosus, and semimembranosus—were checked by this method. There is no evidence that electrical stimulation was used to establish the position of the electrodes in the muscle belly tested. Studies were also made of muscles after tendon transfer. These studies, however, were done by the palpation method.

These basic associations of muscular contraction with the stance and swing phases of walking are also found, to a large extent, in individuals with lower-extremity involvement following poliomyelitis. When tendon transfer in the lower extremity is contemplated, the question often arises whether one can violate the patterns of phasic behavior and expect a functional transfer. For example, if the tibialis anterior, a swing-phase muscle, is transferred posteriorly to the calcaneus, will it be able to change its phase of action and serve as a stance-phase muscle as does the soleus muscle which it is intended to replace or re-enforce? Further-

*Read at the Combined Meeting of the Orthopaedic Research Society and The American Academy of Orthopaedic Surgeons, New York, N. Y., February 1, 1958.

more, if transfers are done within the boundaries of phasic groupings, will these muscles retain their desirable preoperative phasic activity? For example, if the common extensor is transferred to the dorsum of the foot to replace a lost tibialis anterior muscle, will its preoperative swing-phase behavior persist?

If flexor muscles, such as the peronaeus longus, peronaeus brevis, or tibialis posterior are transferred to the calcaneus, a continuation of their stance-phase activity is desirable. When these muscles are transferred forward, however, with the hope that they will act as dorsiflexors during the swing phase of walking, their phasic activity must undergo a conversion from stance to swing to be effective, functioning muscles during locomotion. Such a conversion of phasic activity would apparently require suppression of normal reflexes of reciprocal innervation and the agonist-antagonist reflexes [7] since walking, to a great extent, is an automatic activity.

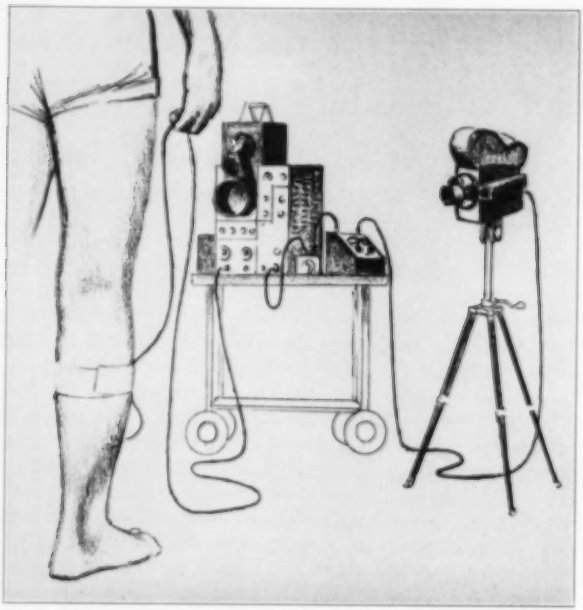

FIG. 1

Drawing of apparatus showing the subject with electrodes in place. The sound motion-picture camera and the oscilloscope recording camera are run simultaneously at the same rate, monitoring the same phenomenon.

Certain transfers may be of considerable benefit to the patient with paralytic disease of the lower extremity although no phasic conversion takes place. If the swing-phase biceps femoris is transferred to the patella, and even though its swing-phase action may continue, it may nevertheless be of value in producing stability at the knee by extending it just prior to the onset of the stance phase of walking. Its benefit during locomotion is then not through duplication of the function of the normal quadriceps muscle which produces knee stability in a different manner: by serving to prevent further flexion or collapse of a slightly flexed knee during the stance phase of walking. An example is presented, however (Fig. 21), in which the transferred biceps femoris became a stance-phase muscle under involuntary conditions.

It is possible that the transferred non-phasic muscle will be detrimental to the patient. For instance, if flexor muscles are transferred to the dorsum of the

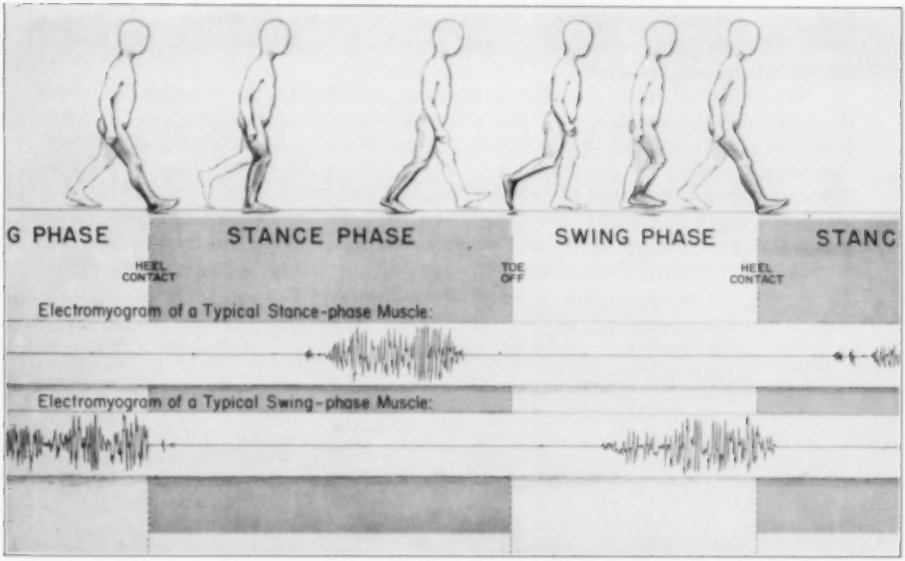

FIG. 2

Idealized electromyograms of stance and swing-phase muscles.

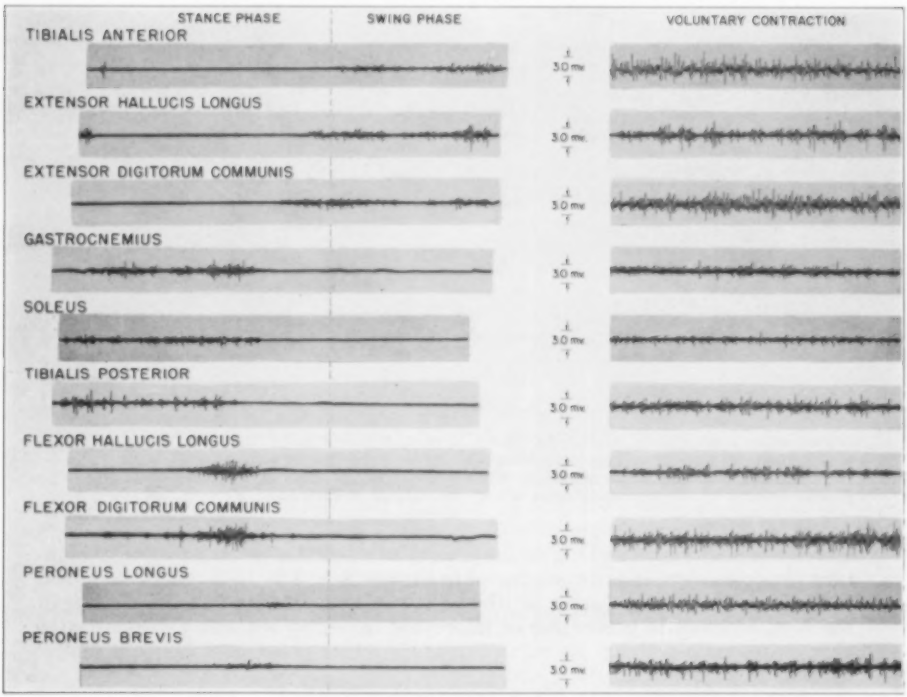

FIG. 3

The normal muscles of the leg. Single typical walking cycles are shown for each normal muscle studied, followed by the electromyogram of voluntary activity. Note that the oscilloscope-sensitivity setting is the same for each study. One subject was used for the entire series.

foot, their stance-phase activity, if retained, will oppose the action of the triceps surae. The effective tension of the calf muscles is then lessened by the tension developed by the transfers.

The ability of many transfers to perform, voluntarily, the function for which they are intended is well known. For instance, the peronaeus longus muscle transferred to the dorsum of the foot may act as an excellent voluntary dorsiflexor. The same muscle may fail completely to act during the swing phase of walking when its action is required to dorsiflex the foot and prevent foot-drop (Figs. 8-A and 8-B). It can be shown in many instances, even during walking, that the patient can make a voluntary effort to use such a transfer with the result that the muscle makes a temporary phasic conversion. This change in the muscle's phasic

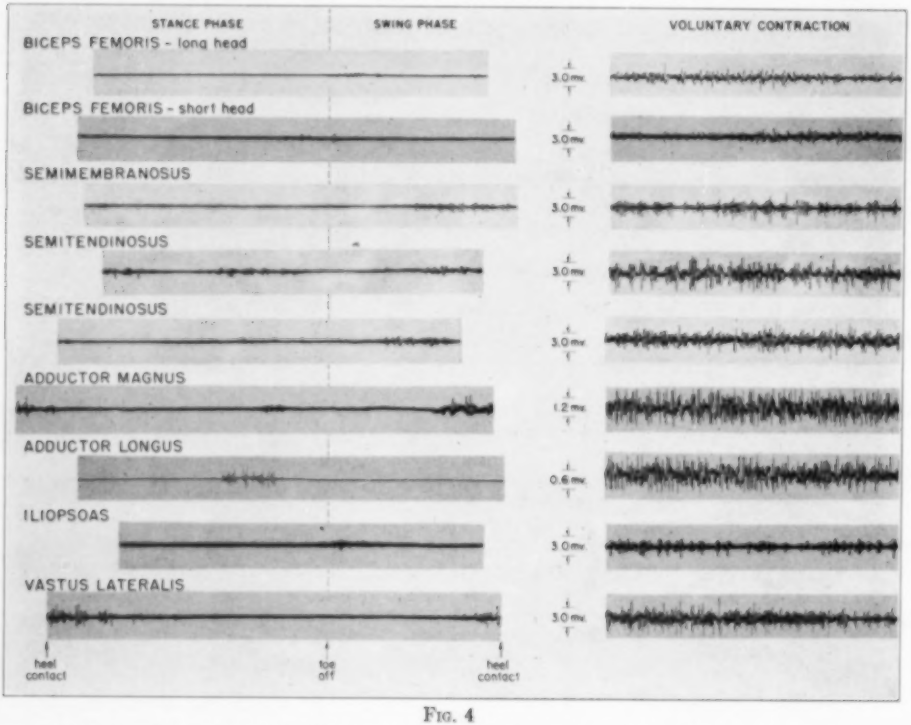

FIG. 4

The normal muscles of the thigh. The relatively minor role of the thigh muscles during walking can be appreciated by comparing the action potential of walking with that produced by voluntary activity. Some variation was observed in the case of the semitendinosus. The phasic activity of the semitendinosus of two individuals is shown.

activity is maintained as long as the patient concentrates on its use. Such voluntary phasic conversion is demonstrated in Figures 8-A, 8-B, 13-A, 13-B, 18-A, and 18-B. If the peronaeus longus or tibialis posterior, transferred to the dorsum of the foot, succeeds in preventing or improving foot-drop without a demonstrable change in phasic activity, its value during the swing phase of walking is similar to that of a checkrein.

Since conservation of all remaining muscle power is a prime consideration in the paralytic lower extremity, the knowledge of what might be expected of the transferred muscle in its new site, particularly regarding its new time of contraction, seems essential. The muscle does not meet the requirements of a

good transfer, although it improves deformity and produces a good voluntary contraction, if it is not making its expected contribution to locomotion.

METHOD

The study, begun in 1954 [2,3], consisted of individual electromyographic tests conducted on 125 muscles in which tendon transfer had been done. Approximately eighty-five patients * were studied. All except two of the patients chosen for study had muscle weakness resulting from poliomyelitis. Often it was possible to make a preoperative, as well as a postoperative, study of the transferred muscle. A series of tests were made on several patients at regular postoperative intervals.

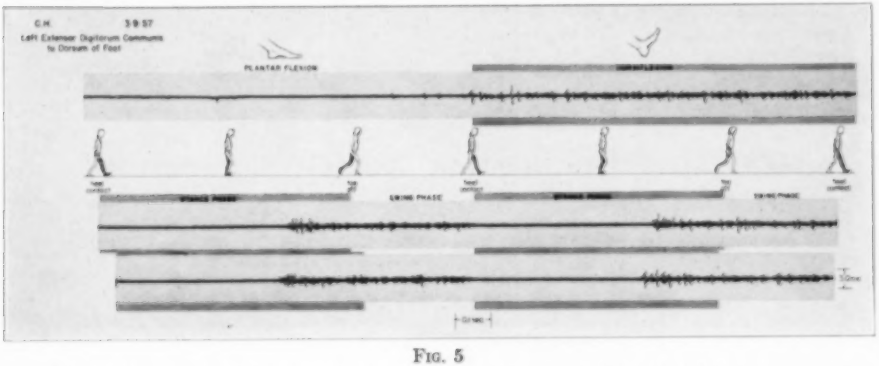

FIG. 5

Subject C. H. Extensor digitorum communis to the dorsum of the foot. The common extensor transferred to the dorsum of the foot demonstrates the characteristic swing-phase behavior of the tibialis anterior group.

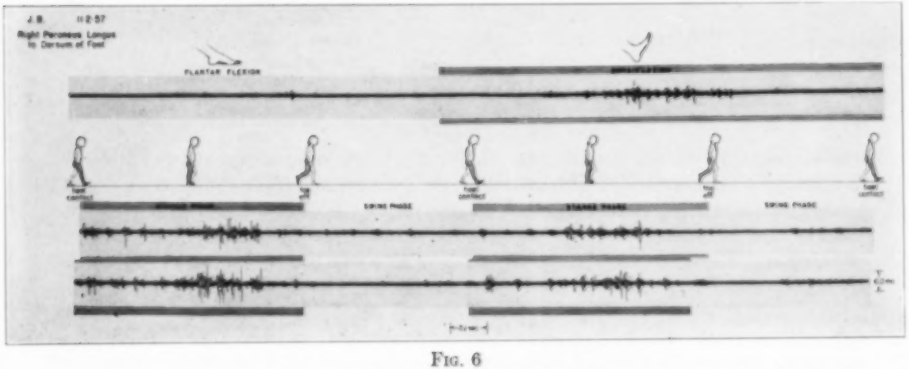

FIG. 6

Subject J. B. Peronaeus longus to the dorsum of the foot. The muscle, in spite of anterior transfer, has retained its stance-phase activity. The electrical activity produced on dorsiflexion reflects the subject's voluntary control of the muscle.

In addition to the eighty-five patients with paralytic muscle involvement of the lower extremity, the muscles of several normal individuals were also studied (Figs. 3 and 4).

The patients studied are classified in Table I according to the type of tendon transfer performed. The patients chosen were those who walked well without

*Many of the patients were made available for the study through the generosity and cooperation of the Highland-Alameda County Hospital, The Children's Hospital of the East Bay, Rancho Los Amigos Hospital Respiratory Center for Poliomyelitis, Los Angeles Orthopaedic Hospital, and the Stanford Lane Hospital.

TABLE I

CLASSIFICATION OF TRANSFERS STUDIED

Group	Phasic	Non-Phasic	No. of Cases	Muscles Tested
Extensor to dorsum	Extensor hallucis longus Extensor digitorum communis		10	10
Flexor to dorsum		Peronaeus longus Peronaeus brevis Tibialis posterior Medial gastrocnemius	20	30
Extensor and flexor to dorsum	Extensor hallucis longus Extensor digitorum communis	Peronaeus longus Peronaeus brevis Tibialis posterior	12	20
Flexor to calcaneus	Peronaeus longus Peronaeus brevis Tibialis posterior Flexor hallucis longus Flexor digitorum communis		12	18
Extensor (tibialis anterior) to calcaneus		Tibialis anterior	8	8
Flexor and extensor to calcaneus	Peronaeus longus Peronaeus brevis Tibialis posterior Flexor hallucis longus Flexor digitorum communis	Tibialis anterior	5	10
Extensor to dorsum and flexor to calcaneus	Extensor hallucis longus Extensor digitorum communis Peronaeus longus Flexor hallucis longus		1	4
Hamstrings to patella		Biceps femoris-short head Biceps femoris-long head Semitendinosus Semimembranosus	17	22

appliances and with a continuous regular gait, rapidly enough to produce the rhythm of phasic activity. The muscles studied met the usual criteria of a good tendon transfer: (1) deformity was improved and (2) voluntary control of the muscle was shown. Most of the studies were made on normal and good muscles. It is often difficult to penetrate poor muscles with the electrodes and to stimulate them electrically in order to verify the position of the electrodes. Weak muscles may require high amplification. This produces technical difficulties such as the appearance of electrical interference. Occasionally, excessively high amplification produced faint recordings of adjacent, more vigorous muscles. These difficulties were not encountered in good or normal muscles where lower amplification could be used. In these subjects it was possible to stimulate the muscle adequately and definitely verify the position of the electrodes. Many of the records were checked by repeating the postoperative test. Dual-wire internal electrodes were used. The electrodes were connected by shielded cable to the preamplifier of a cathode-ray oscilloscope. The oscilloscope tracing was photographed with a continuous recording oscilloscope camera. The vertical output of the cathode-ray oscilloscope was connected to the amplifier of the sound motion-picture camera. Thus, simultaneous records were made at the same speed by both recording instruments. The equipment used and its assembly is shown in Figure 1.

Most of the recordings were made at a frequency range of 60,000 cycles per second to eighty cycles per second. One recording from each muscle was also

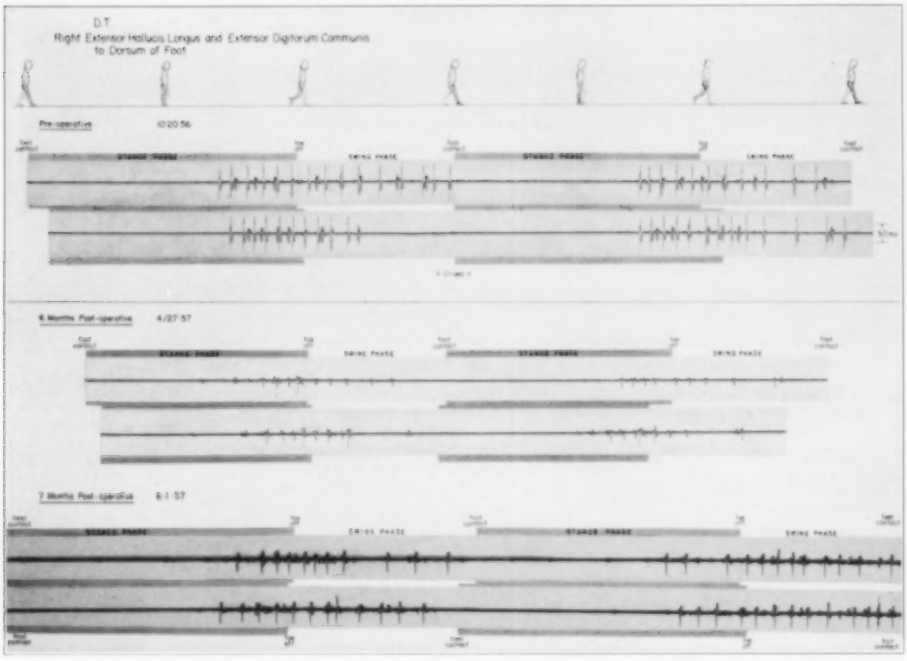
D.T.
Right Extensor Hallucis Longus and Extensor Digitorum Communis to Dorsum of Foot
Pre-operative 10 20 56
6 Months Post-operative 4/27/57
7 Months Post-operative 6-1-57

FIG. 7

Subject D. T. Preoperative and postoperative studies made of the extensor hallucis longus and extensor digitorum communis muscles. Intermittent action potentials of large amplitude are shown; the muscle had some postpoliomyelitic weakness. Six months postoperatively, electrical activity was considerably diminished. Seven months following transfer the muscle regained its preoperative electrical intensity. The preoperative pattern of swing-phase activity has been retained.

usually made using a lower frequency limit of eight cycles per second. This lower limit was not used in most of the graphs reproduced here because of irregularity of the base line. However, no significant discrepancy between the recordings made at 60,000 cycles per second to eighty cycles per second and those made over a range of 60,000 cycles per second to eight cycles per second was noted (Fig. 17). Normal musculature required a calibrated oscilloscope-sensitivity setting of 0.5 millivolt or 1.0 millivolt per centimeter. The postpoliomyelitic muscle usually required a setting of 1.0 millivolt or 2.0 millivolts per centimeter. The oscilloscope-sensitivity settings used during the test are recorded on each figure shown. The same setting was used for each study in order to make the various activities such as level walking, walking on stairs, and voluntary isotonic contraction while in a sitting position, reflect comparative amounts of electrical activity produced. Since the reduction factor of the oscilloscope camera is six, the oscilloscope-sensitivity setting is multiplied by this number in order to express the calibration of each record.

By setting the oscilloscope sensitivity so that peaks of electrical activity during walking, ascending stairs, and voluntary contraction are included on the oscilloscope screen, one is able to place the amount of electrical activity of each action in its proper relationship. For example, Figure 4 reveals the relatively minor role of the hamstring muscles during walking compared with flexion of the knee and the relatively low level of quadriceps activity during walking compared with extension of the knee.

Accurate placement of the electrodes within the belly of the muscle to be tested was ascertained by the use of faradic stimulation through the electrodes

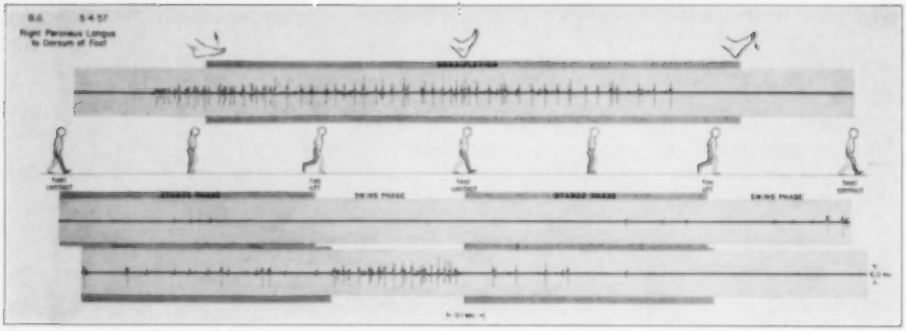

FIG. 8-A

Subject B. G. Peronaeus longus to the dorsum of the foot. There is no definite pattern of activity and for considerable periods the patient has no involuntary use of the muscle.

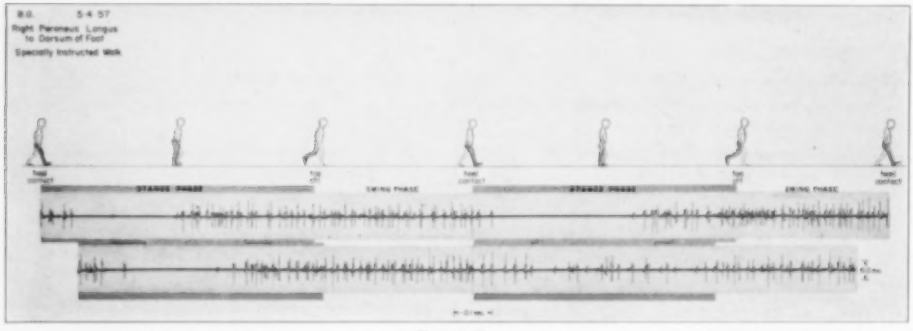

FIG. 8-B

There was useful swing-phase action following specific instructions. This patient was given extensive physical therapy.

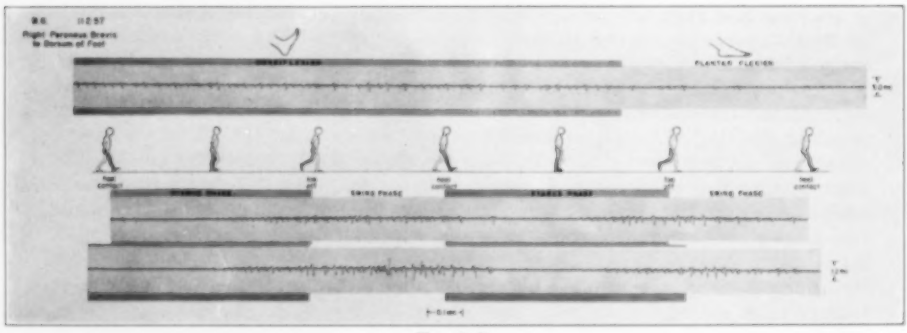

FIG. 8-C

before and after each test. No data were accepted unless isolated contraction of the stimulated muscle could be observed.

Oscillograms can be readily plotted for continuous walking cycles from the data obtained. The occurrence of the events of walking are recorded by analysis of the individual frames of the sixteen-millimeter film and transferred to the oscillogram on the thirty-five-millimeter paper of the oscillograph camera. The action potential during walking is thus precisely synchronized with the phases

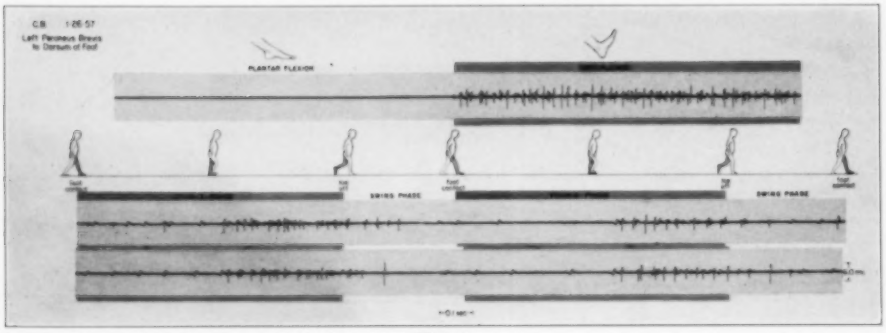

FIG. 9

Figs. 8-C and 9: Subjects B. G. and C. B. Peronaeus brevis to the dorsum of the foot. The results are shown of two patients in whom the peronaeus brevis was transferred to the dorsum of the foot. One figure demonstrates almost complete conversion to the swing phase of walking while the second, very little swing-phase activity.

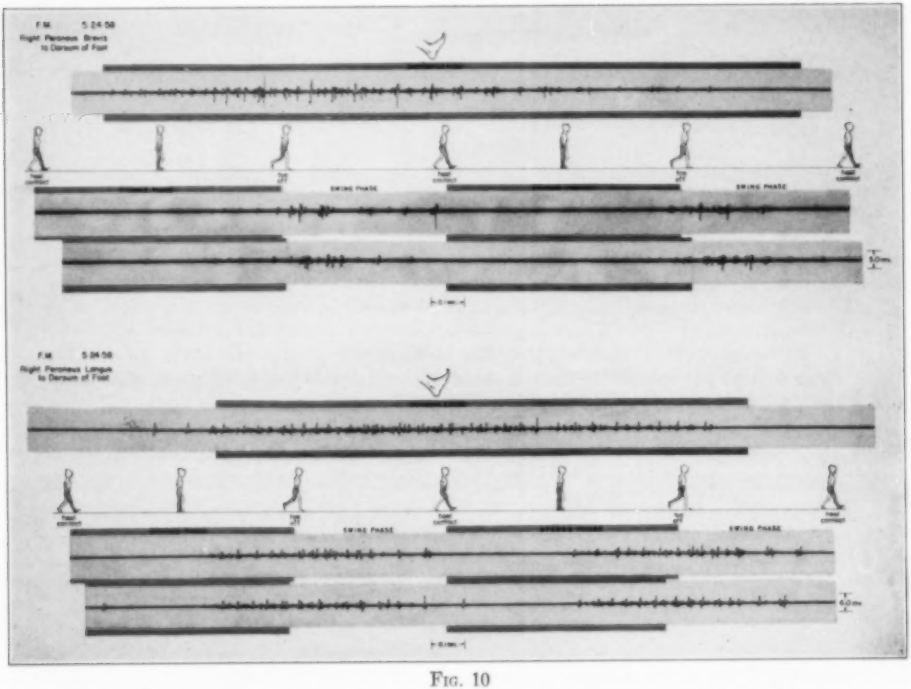

FIG. 10

Subject F. M. Peronaeus brevis and peronaeus longus to the dorsum of the foot. The transfers were done ten years prior to the tests. Conversion to the swing phase was shown by both muscles. No physical therapy was given.

of the walking cycle. The same oscillation, displayed by the oscilloscope and recorded by the oscilloscope camera as the subject walks, is simultaneously recorded on the sound track of the sound camera. A great deal of material may be reviewed in a short time with the use of the sound film, much more than is covered in the charts presented in this paper, where only a single voluntary con-

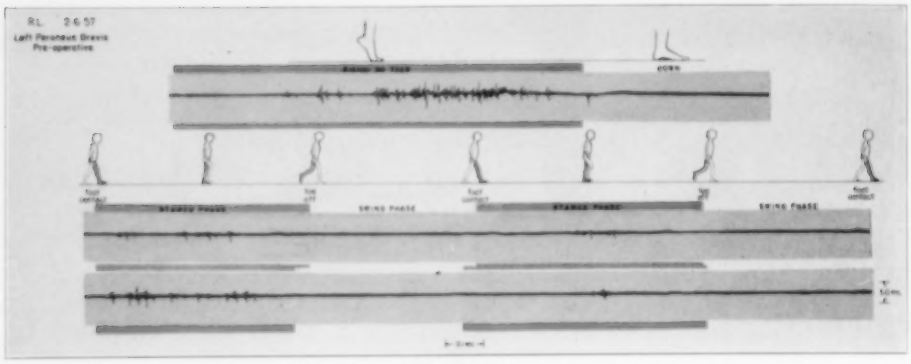

FIG. 11-A

Subject R. L. Preoperatively, the peronaeus brevis muscle demonstrates the usual stance-phase activity. The muscle is not used extensively during normal walking.

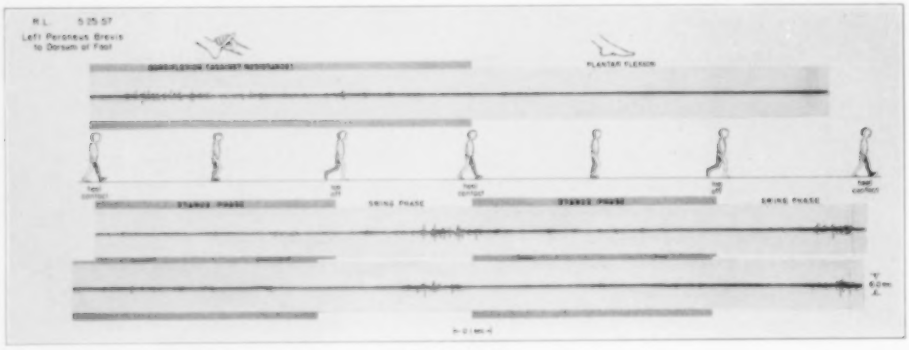

FIG. 11-B

Three months postoperatively there is decisive conversion to the swing phase of walking. No instruction was given before the recording was made.

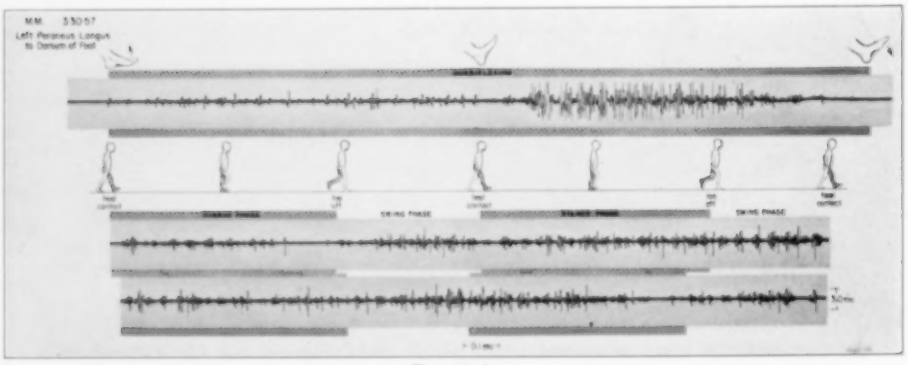

FIG. 12-A

Figs. 12-A through 12-C: Subject M. M. The peronaeus longus, peronaeus brevis, and extensor digitorum communis tendons have been transferred to the dorsum of the foot.

Fig. 12-A: The peronaeus longus muscle demonstrates continuous activity. There is, however, excellent voluntary use of the muscle as a dorsiflexor.

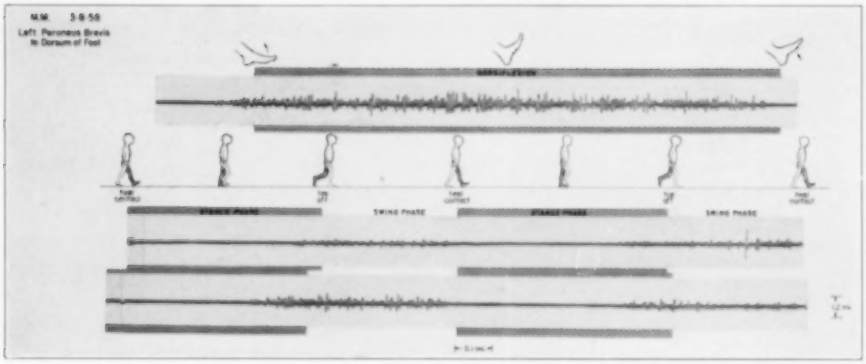

FIG. 12-B

The peronaeus brevis muscle has made a complete conversion to the swing phase of walking.

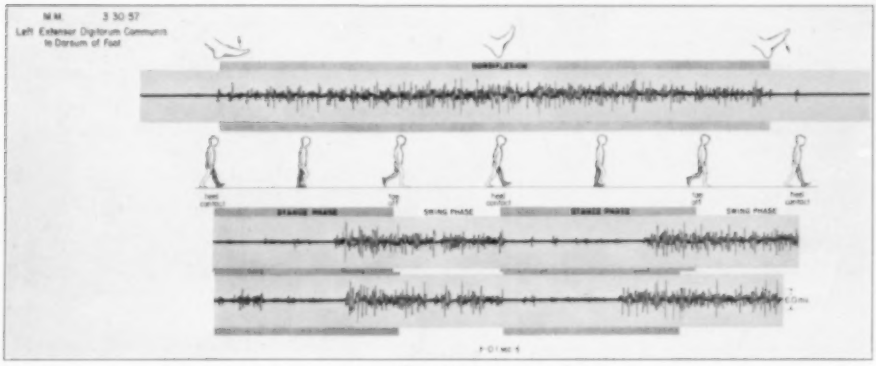

FIG. 12-C

The common extensor also demonstrates the anticipated excellent swing-phase activity.

traction and four consecutive walking cycles are usually presented for each test.

The procedure readily yields the following information: (1) the phasic activity of the muscle for repeated walking cycles, (2) the duration of each muscle contraction, and (3) the electrical intensity or population of motor-unit activity.

After the injection of local anaesthesia into the patient's skin, the wire electrodes are inserted in the muscle. The subject is then asked to walk in his usual manner. No instruction is given which might alter the subject's customary gait. After tracings of normal walking are made, the effect of specific instruction may be recorded. For instance, if the peronaeus longus, transferred to the dorsum of the foot, appears to be silent, irregular, or ineffective, data may be taken after the patient is asked to concentrate on the use of the muscle as a dorsiflexor as he walks. Tracings from a muscle of this type are shown in Figures 8-A and 8-B.

Evidence of the reliability of the method is found in its ability to reproduce, on repeated tests, the same particular pattern of electrical activity for a given muscle. In two normal individuals, when the electrodes were placed in the upper one-third of the adductor magnus the muscle produced a characteristic burst of activity during the swing phase followed by a lesser burst of activity during the stance phase of walking (Fig. 4). Tracings obtained from the contralateral muscle of the same subjects were almost identical. The two bursts of activity are thought to represent the sciatic and obturator innervated portions of the muscle. After the peronaeus longus muscle of one patient had been transferred

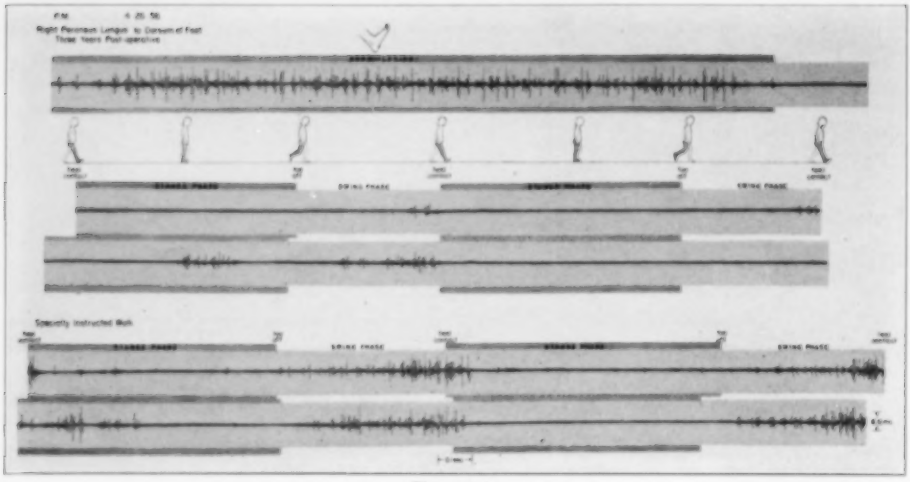

FIG. 13-A

Figs. 13-A and 13-B: Subject P. M. The peronaeus longus and extensor hallucis longus muscles have been transferred to the dorsum of the foot.

Fig. 13-A: The peronaeus longus muscle demonstrates spasmodic swing-phase activity. The usefulness of the muscle increases markedly when the patient concentrates on its use following instruction.

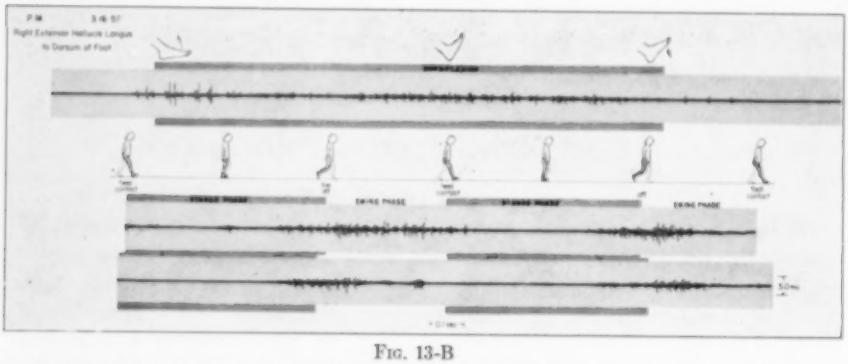

FIG. 13-B

In contrast, the extension hallucis longus muscle has retained its spontaneous swing-phase activity.

to the dorsum of the foot, it demonstrated a unique pattern of bursts of activity during the middle portions of both swing and stance. The muscle reproduced a remarkably similar pattern of activity at a subsequent test (Figs. 14-A and 14-B).

RESULTS

Phasic transfers, such as extensor transfers, to the dorsum of the foot appeared to regain their preoperative swing-phase activity in as short a time as seven or eight weeks. An index to the degree of recovery and effectiveness of the muscle with tendon transfer is found in its postoperative tracing when its electrical activity and population of motor units are compared with the preoperative tracing. Studies at repeated intervals, postoperatively, were assembled (Fig. 7) to show the customary progressive return of electrical activity. Other phasic transfers, such as peroneal muscles, or flexor muscles to the calcaneus, similarly regained their preoperative phasic activity (Figs. 18-C and 18-D).

In general, non-phasic transfers such as hamstrings to patella, tibialis ante-

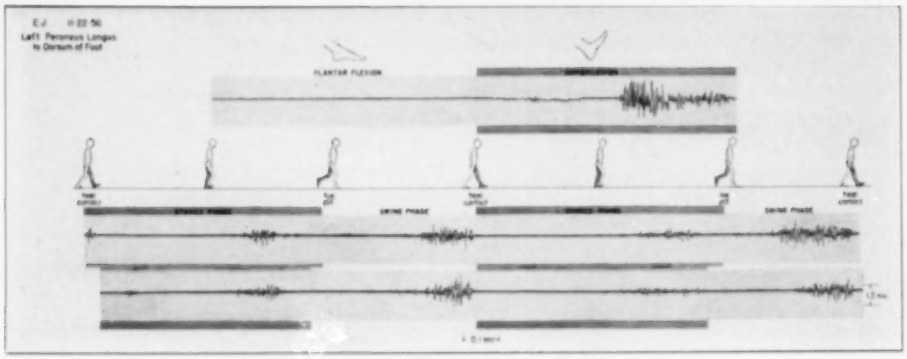

FIG. 14-A

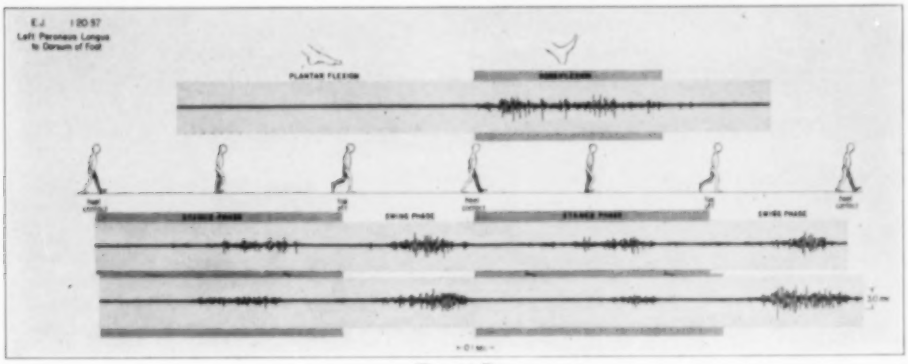

FIG. 14-B

Figs. 14-A and 14-B: Subject E. J. Two tests of the peronaeus longus muscle which has been transferred to the dorsum of the foot. This transfer was done because of a traumatic severance a few years previously of the tibialis anterior. Almost identical patterns are obtained from both tests although it is noted that the oscilloscope sensitivity is not the same. The peronaeus longus, now serving as a dorsiflexor, has a considerable amount of useful swing-phase activity although some stance-phase activity persists.

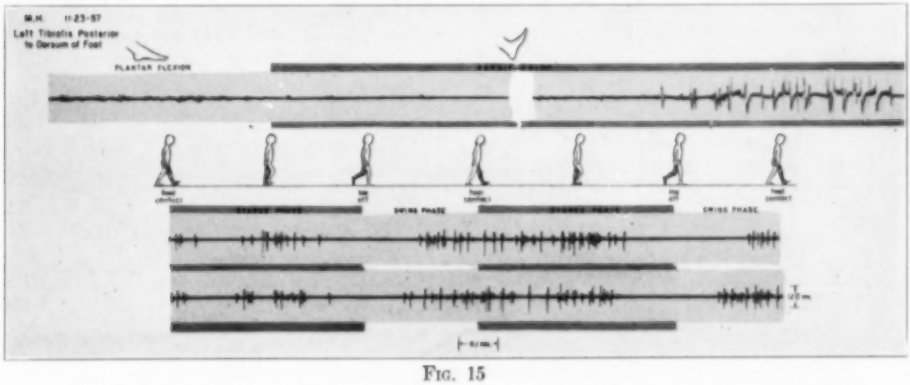

FIG. 15

Subject M. H. Tibialis posterior to the dorsum of the foot. Following transfer of the tibialis posterior to the dorsum of the foot, the muscle, for the most part, retains its stance-phase activity.

rior to heel, and flexors to the dorsum of the foot demonstrated a strong tendency to retain their preoperative pattern of phasic activity, failing to make the desired conversion to the phase of the muscle for which they were substituted (Figs. 5, 8-A, 8-B, 13-A, 13-B, 15, 19-A, and 19-B).

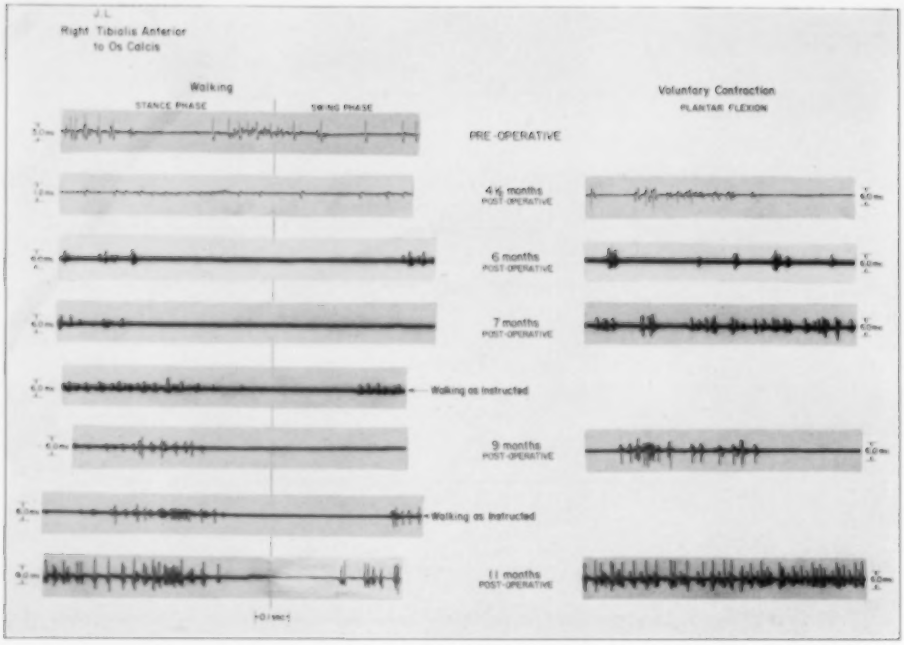

FIG. 16

Subject J. L. Tibialis anterior to the calcaneus. Preoperatively, the patient's calf muscles were paralyzed. The tibialis anterior had a bizarre phasic behavior. For several months after transfer to the calcaneus, there was marked loss of electrical activity. At seven months, the patient could make excellent voluntary use of the muscle during walking. Some spontaneous stance-phase activity appeared nine months postoperatively. Eleven months postoperatively, involuntary stance-phase action is demonstrated. Voluntary plantar flexion is shown in the column on the right side of the chart. Intensive physical therapy was employed.

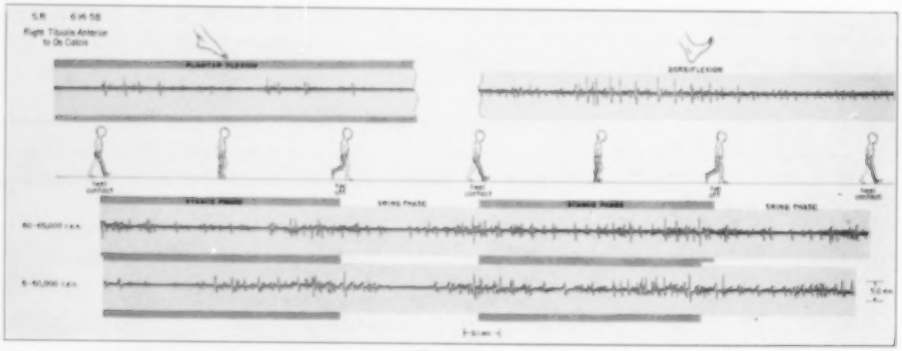

FIG. 17

Subject S. R. Tibialis anterior to the calcaneus. One year postoperatively more electrical activity is recorded on dorsiflexion than on plantar flexion. There is no pattern of activity during walking. Physical therapy was given weekly for one year.

Among the non-phasic transfers, conversion was demonstrated in a number of instances:

Tibialis Anterior to the Calcaneus

In the thirteen patients studied in whom the tibialis anterior tendon was transferred to the calcaneus, four transfers showed a significant amount of ac-

quired stance-phase electrical activity (Figs. 16, 17, 18-A, and 18-B). Where the tendon was transferred to the calcaneus as a single procedure, phasic conversion appeared to be a great deal more likely than if the tendon were transferred simultaneously with others. Apparently, training the muscle of the non-phasic type is more effective when it can be applied to a single muscle, its tendon having been transferred individually to its new insertion. Phasic conversion of transfer of the tibialis anterior to the calcaneus was not evident before an eight-month postoperative period had elapsed.

Peronaeus Longus to the Dorsum

Two of the thirty-two transferred muscles studied showed excellent involuntary swing-phase activity (Fig. 10). Another muscle transfer of this type demonstrated bursts of activity during swing and stance. Other peronaeus longus transfers to the dorsum of the foot showed some activity throughout the entire walking cycle. A frequent result of peronaeus longus transfer to the dorsum of the foot was retention of the original stance-phase pattern.

Peronaeus Brevis to the Dorsum

Ten of the twelve patients studied demonstrated a remarkable conversion from stance to the swing phase of walking. This spontaneous conversion was observed as early as three months postoperatively.

Hamstrings to Patella

Study of seventeen patients with biceps transfers to the patella showed that swing-phase activity was usually retained (Figs. 19-A and 19-B). In two patients where swing-phase activity persisted during walking, spontaneous stance-phase activity developed when the subject ascended stairs. Two patients with biceps transfer to the patella, however, demonstrated complete conversion to the stance phase. In Figure 21 it is noted that, preoperatively, the patient walked with the involved knee in hyperextension during the stance phase. The transferred biceps femoris, with its newly acquired stance-phase activity, made it possible for the subject to walk with the knee slightly flexed. This is thought to be the function of the normal quadriceps mechanism during level walking.

Figure 20 shows the tracings from a semitendinosus muscle transferred to the patella. No preoperative studies were made on this subject. The patient, in whom the biceps femoris was also transferred to the patella, developed complete voluntary extension of the knee. The tracings show that, postoperatively, the semitendinosus is a stance-phase muscle. The biceps femoris transfer in this patient failed to undergo phasic conversion. Possibly, it was not necessary for the semitendinosus to make a complete phasic change. Reference to the records of normal thigh muscles (Fig. 4) reveals that the activity of the normal semitendinosus may extend into the stance phase. Preoperative testing of this muscle might have revealed that such was the case. Preoperative testing of such muscles in the paralytic lower extremity may be of great value in selecting the muscle most adaptable for transfer, if a choice is available.

DISCUSSION

There is great value in understanding the phasic activity of normal muscles. In the paralytic subject, it is valuable to establish the phasic activity of the muscles which might be under consideration for transfer. Where a choice of muscles available for transfer exists, knowledge of the phasic activity of those muscles is of obvious importance in planning the procedure. For example, if hamstring muscles are to be brought forward to replace or re-enforce the quadriceps, a transfer having some stance-phase activity may be the muscle of choice. Furthermore, if one has a choice between certain non-phasic transfers, such as the peronaeus brevis or peronaeus longus, for transfer to the dorsum of the foot, one

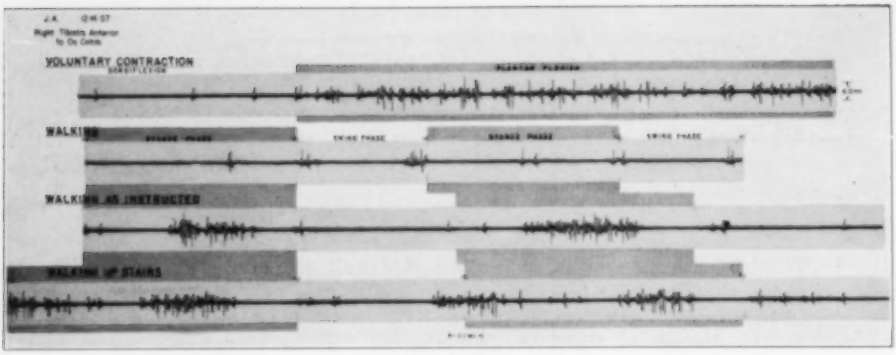

FIG. 18-A

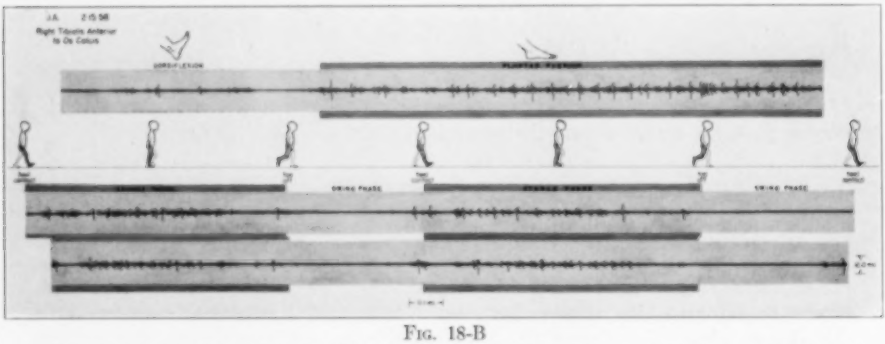

FIG. 18-B

Figs. 18-A and 18-B: Subject J. A. Tibialis anterior to the calcaneus. Studies made six and eight months postoperatively are shown. At six months, the patient still had no involuntary stance-phase activity. Eight months postoperatively, the transfer had become a stance-phase muscle; intensive training was given. Previously, the peronaeus longus and flexor hallucis longus tendons were transferred to the calcaneus. These transfers were done as separate procedures (Figs. 18-C and 18-D).

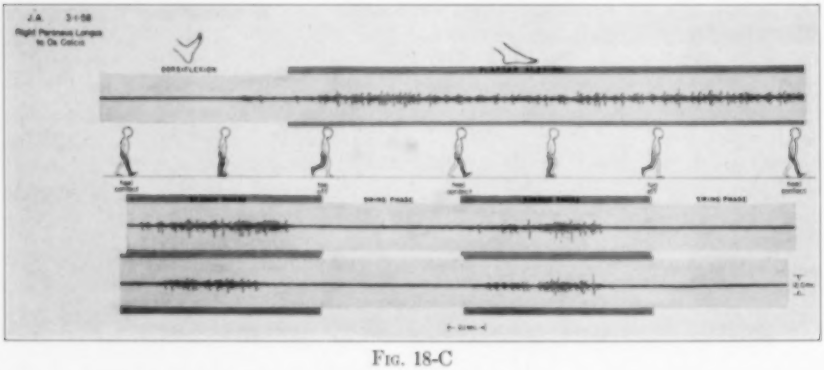

FIG. 18-C

should observe that one muscle possesses far more likelihood of conversion to the swing phase than the other.

Where a choice is available between a phasic and non-phasic transfer, such as the common extensor and the peronaeus longus to the dorsum of the foot, one can be confident that the common extensor will retain its swing-phase activity, while the likelihood of conversion of the stance-phase peronaeus longus to the swing phase is remote. The phasic transfers, such as extensors to the dorsum of

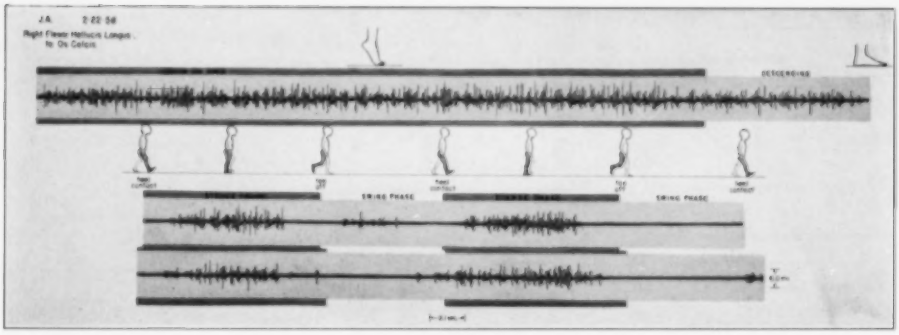

FIG. 18-D

Fgs. 18-C and 18-D: Subject J. A. The peronaeus longus and flexor hallucis longus muscles transferred to the calcaneus readily demonstrate their desired stance-phase behavior.

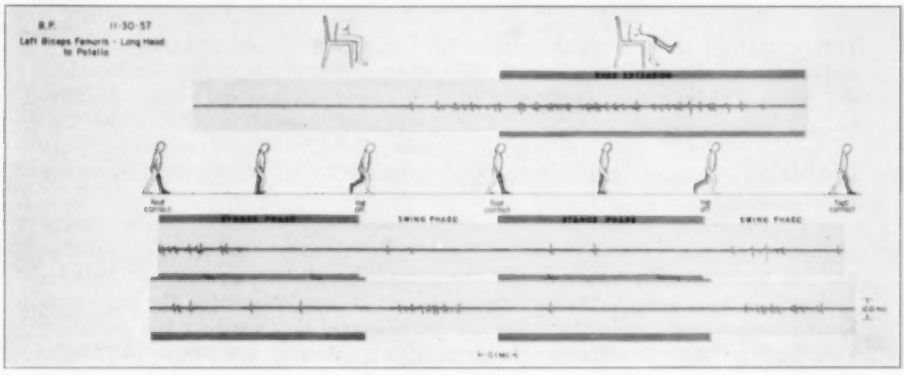

FIG. 19-A

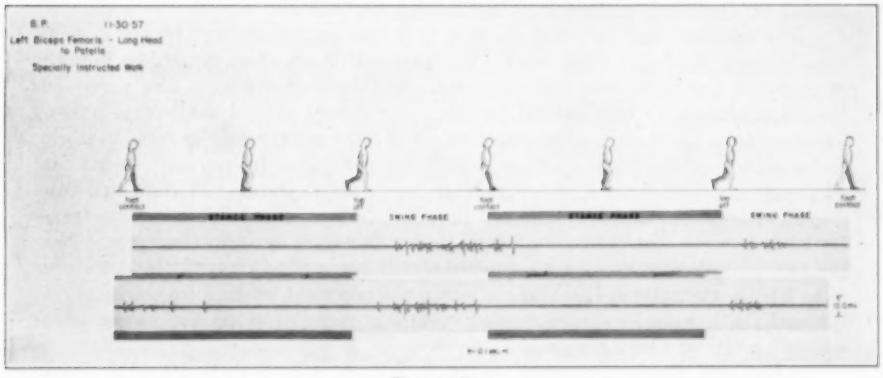

FIG. 19-B

Figs. 19-A and 19-B: Subject B. P. Biceps femoris transferred to the patella. The long head of the biceps shows swing-phase behavior. Temporary conversion does not follow instruction. Intensive training was given postoperatively.

the foot or flexors to the heel, regain most of their electrical activity after operation.

Where phasic transfers are combined with non-phasic transfers at one procedure, considerable difficulty is encountered in training the non-phasic muscle.

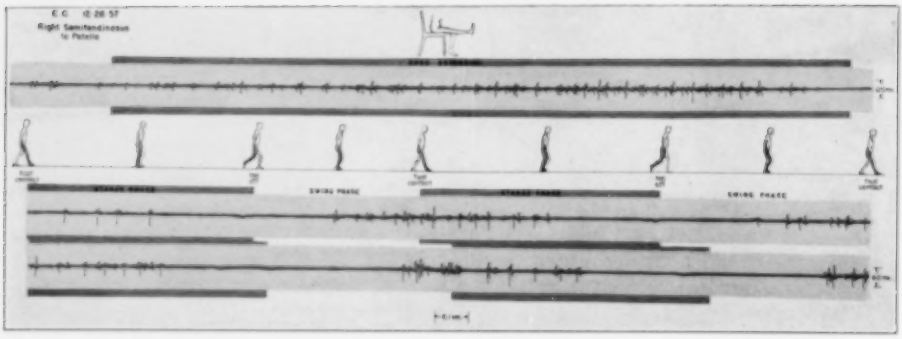

FIG. 20

Subject E. C. Six months after transfer of the right semitendinosus and biceps femoris tendons into the patella. His quadriceps muscle was rated as poor. As indicated by the figure, he now has complete voluntary extension. The semitendinosus demonstrated a remarkable amount of stance-phase activity, its behavior resembling the action of the quadriceps muscle.

If the tibialis anterior is transferred to the heel along with flexor muscles, phasic conversion is very unlikely. Occasionally, the peronaeus longus is transferred to the dorsum along with an extensor. In such combinations, there is no instance recorded where phasic conversion of the peronaeus longus has taken place. Apparently non-phasic transfers, if transferred individually, can be trained far more successfully. The non-phasic transfer, if accompanied by phasic muscles to the same site, appears to fail.

The difference in the fate of the transferred peroneal muscles to the dorsum of the foot is of considerable interest. As Schaeffer stated, the ankle joint is found only in mammals. In lower forms, the peroneal muscles are anterior muscles and serve as extensors. As the calcaneus migrated beneath the talus, the peronaeus longus tendon and, probably later, the brevis, were displaced to the posterior aspect of the lateral malleolus. This migration apparently is more recent in the case of the peronaeus brevis as it can still be found in some amphibians to be anterior to the lateral malleolus, although the peronaeus longus has succeeded in migrating posterior to the lateral malleolus.

The extensor and peroneal rudiments in the human embryo [1,4] are a single muscle mass until the sixth week. The peroneal mass then separates from the extensor as the individual peroneal rudiments become distinct. The peronaeus longus tendon is at first lateral to the rudimentary lateral malleolus, passing posterior to it when the embryo reaches the size of twenty millimeters. Posterior transposition of the tendon of the developing peronaeus brevis must await that of the peronaeus longus if it is to retain its position anterior to that structure.

In several of the subjects tested in whom both of the peroneals were transferred anteriorly, the peronaeus longus failed to adapt itself to the swing phase, the peronaeus brevis making a complete phasic conversion often without training (Fig. 9). In one patient, however, in whom the peroneal tendons were transferred forward, both muscles demonstrated complete conversion to the swing phase without training (Fig. 10).

Additional studies presented (Figs. 5, 6, 8-A, 8-B, 8-C, 9, 10, 11-A, 11-B, 12-A, 12-B, 12-C, 13-A, and 13-B) clearly showed a marked difference in the ability of the peronaeus longus and peronaeus brevis muscles to undergo phasic conversion. The factors effecting phasic conversion were:

1. Training in the form of re-education directed toward the use of the muscle during the proper phase of the walking cycle appears essential in certain transfers. The tibialis anterior transferred to the calcaneus undergoes phasic conversion only after several months of intensive physical therapy. The only subjects with hamstring transfer to the patella which were followed by phasic conversion

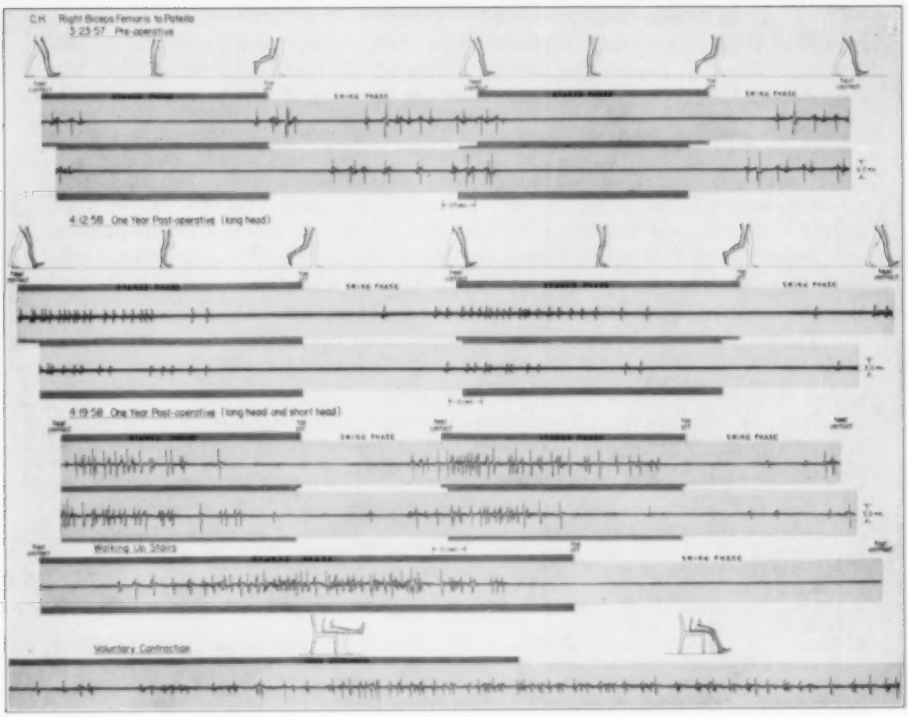
C.H. Right Biceps Femoris to Patella
3-23-57 Pre-operative
4-12-58 One Year Post-operative (long head)
4-19-58 One Year Post-operative (long head and short head)
Walking Up Stairs
Voluntary Contraction

FIG. 21

Subject C. H. The patient had poor quadriceps strength preoperatively and was unable to extend the knee. Four months postoperatively, she could extend the knee completely. Preoperatively, the biceps femoris muscle demonstrated swing-phase behavior. Postoperatively, there is spontaneous, involuntary stance-phase behavior. The muscle is used extensively on ascending stairs as indicated by the amount of electrical activity. Preoperatively, the patient walked with a slight amount of recurvatum. Postoperatively, she walks with a slightly flexed knee. The phasic behavior and function of the transfer thus resembles that of the normal quadriceps muscle.

were extensively trained by the physical therapist. The patients with transfers of the peronaeus longus to the dorsum in whom phasic conversion took place, received little or no instruction. Many others were extensively treated for several years but produced no swing-phase activity. Conversion of the peronaeus brevis transferred to the dorsum appears to be a spontaneous phenomenon.

2. Mixing of phasic and non-phasic transfers uniformly dooms the non-phasic transfer to failure of conversion unless the non-phasic transfer is done as a separate procedure.

3. The time interval from onset of disease to date of transfer cannot be related to likelihood of conversion.

4. Bracing or postoperative splinting, while helpful in maintaining physiological length and vigor of the muscle, cannot be correlated with phasic conversion.

SUMMARY

The sound motion-picture camera, in conjunction with the cathode-ray oscilloscope using internal individual muscle electrodes, represents an excellent and practical method for recording the phasic activity of the muscles of the lower extremity. The importance of phasic activity in the normal and the preoperative and postoperative paralytic patient is demonstrated.

Phasic transfers in general retain their preoperative phasic activity. They

also appear to regain their preoperative duration of contraction and electrical intensity. Many non-phasic transfers retain their preoperative pattern of phasic activity, failing to assume the desired action of the muscle for which they are substituted. Certain non-phasic transfers are capable of phasic conversion.

CONCLUSIONS

The method described is a simple procedure by which reconstructive tendon transfers in the lower extremity can be better evaluated. The test can be conducted with a limited amount of equipment and may be relied upon to produce an excellent display of the electrical activity of the muscle. The orthopaedic surgeon engaged in the rehabilitation of the paralytic patient can profit by electromyographic evaluation before and after tendon transfer.

The phasic transfer, in general, is superior to the non-phasic transfer. Results of the phasic transfer are predictable. In some instances, however, non-phasic transfers can undergo phasic conversion.

It is possible that certain instances of prompt, spontaneous phasic conversion may be attributed to the use of ancestral pathways—once used in forebears where the muscle had the function of the transfer in its new position.

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DISCUSSION

Dr. Fred C. Reynolds, St. Louis, Missouri: Sperry showed that crossing the flexor and extensor nerves of an extremity in the rat resulted in permanent loss of function. Similar experiments carried out in the monkey, however, revealed that with proper educational stimuli and time, the monkey was able to activate the flexor-muscle group to perform a duty normally carried out by the extensor muscles. It has long been known that in man, voluntary activity may be established quite readily after antagonistic tendon transfer. Nicolandoni, in 1880, is credited with the first tendon transfer; this was the peronaeus longus to the calcaneus. Patient and accurate observations by orthopaedic surgeons through the years have placed tendon transference on a sound clinical basis; for instance, the biceps tendon to the patella for quadriceps paralysis. Dr. Crego, in 1931, reported a long-term follow-up of sixty-three patients, indicating that for this operation to be successful the operative procedure must be accurately carried out; the postoperative flexion of the hip and knee must be prevented; and that the most important consideration by far was adequate training and instruction in the postoperative period. He found that with proper training the transplanted biceps tendon would be completely dissociated from its former activity in a high percentage of patients, that is, relaxation of the transplantation on flexion of the knee, and relaxation of the remaining hamstrings on extension of the knee. In some instances, the inner hamstring contracted with extension of the knee, but the biceps was relaxed on flexion; in others, the biceps would contract on both flexion and extension. The failure in this group was one patient who resisted instruction and could not be taught to use the transposed muscle properly.

In 1941, Weiss and Brown made electromyelographic studies of eighteen patients who had had transposition of the biceps tendon to the patella. They found that time and education were required to eliminate contraction of the biceps in flexion motion of the knee. But even after long study and use, relapses would occur with fatigue, lack of concentration, or spon-

(Continued on page 222)

Fracture of the Intercondylar Eminence of the Tibia*

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Fracture of the intercondylar eminence of the tibia is a poorly understood injury. Since it is an intra-articular fracture, it is viewed with some alarm. A widely used American textbook on fractures [3] states: "If the displaced fragment cannot be reduced, and if full extension at the knee cannot be obtained, the joint should be opened and the detached fragment should be removed or fixed in its normal position with a fine wire." A British text on fractures [5] states: "It may be possible to reduce the displacement by manipulation of the joint under anaesthesia, but if radiographs do not show accurate replacement operative reduction is advisable." No large series of cases of this fracture with long-term end results could be found in the literature. Most reports present one case and advocate methods of treatment based on experience with few patients. The treatments advocated are too radical and in most instances unnecessary. It is the purpose of this paper to present criteria for treatment drawn from a study of forty-five patients who had fracture of the intercondylar eminence of the tibia. Ten of the patients were adults, and thirty-five were children who had not yet reached skeletal maturity. It was possible to determine end results in all but two patients. The average follow-up was three years. The longest period was twenty years; the shortest, six months.

This series of patients indicates that fracture of the intercondylar eminence of the tibia in the adult is far less common than in the child and adolescent; but the fracture is a more serious injury in the adult than in the child. In the adult, this fracture is the result of greater violence and, consequently, even though the major bone damage is confined to the intercondylar area of the tibia, there is usually extensive damage to the supporting ligaments and gliding surfaces of the knee joint. A marked degree of permanent disability is frequent in the adult after fracture of the intercondylar eminence of the tibia. Of the ten adult patients evaluated, the result in seven was poor, and in only three was it satisfactory. That four of these patients had complete tear of the medial collateral ligament (Fig. 1), resulting in marked lateral instability of the knee joint, explains these results. Two had associated fracture of the fibular neck and damage to the lateral margin of the lateral tibial plateau; another had a large piece of the articular surface of the medial condyle sheared off. During childhood and adolescence, this fracture occurs as the result of less severe violence. It is usually an isolated injury, rarely accompanied by damage to other supporting structures of the knee. In the rare instance in which there is any damage to other than the anterior cruciate ligament, this damage is minor. An excellent recovery is the general rule during childhood and adolescence. The cases reported in this series were gathered from three sources. Twelve were from the files of the Los Angeles Children's Hospital; twenty-seven, of which ten were adults, were gathered from the files of the Los Angeles County General Hospital; six were private patients of Dr. Francis McKeever. Of the forty-five patients, fourteen were treated by one of the authors. The other patients were treated by surgeons and residents connected with the institutions mentioned.

*Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 31, 1957.

However, the final follow-up examination of each patient was made by one or both of the authors. There were two patients treated before 1935; nineteen between 1935 and 1945; and twenty-four between 1945 and 1954, making a total of forty-five patients from 1933 to 1954.

In the thirty-five children, this fracture occurred in eighteen boys and seventeen girls (Table I). Fracture of the intercondylar eminence of the tibia was not seen in patients under the age of seven. It occurred most frequently in children between the ages of eight and thirteen; twenty-nine patients were in this age group. It was possible to determine the type of injury which produced this fracture in thirty patients: seventeen fell from a bicycle; six fell while running, hurdling, playing baseball, or football; seven fell while avoiding an on-coming automobile or were struck by an automobile. In a high percentage of accidents, the fall was probably on the bent knee with a simultaneous, violent internal twist of the tibia

TABLE I

FRACTURE OF THE INTERCONDYLAR EMINENCE OF THE TIBIA IN FORTY-FIVE PATIENTS

	Thirty-five Children (17 girls, 18 boys)								
Age (*years*)	7	8	9	10	11	12	13	14	15
No. of Patients	2	7	5	1	6	2	8	2	2
Type of Injury									
Fall from bicycle								17	
Fall in athletics								6	
Struck by automobile								7	
Unknown								5	

	Ten Adults (3 women, 7 men)			
Age (*years*)	20-30	30-40	40-50	50-60
No. Patients	5	1	3	1
Type of Injury				
Struck by automobile		6		
Automobile accident		2		
Motorcycle accident		1		
Fall		1		

on the femur. This fracture occurred so frequently in bicycle accidents that it seems reasonable to state categorically that a child between the ages of eight and thirteen who has a painful swollen knee after falling from a bicycle must be assumed to have a fracture of the intercondylar eminence of the tibia until it is proved otherwise.

A clinical sign of a fracture of the intercondylar eminence of the tibia is large, rapidly developing effusion of the knee after trauma. The knee joint is held in a position of flexion and any attempt to extend the knee causes severe pain. A few degrees of motion from the position of the fixed flexion deformity may be possible; however, flexion is also markedly restricted. The flexion deformity which resists correction is not caused by the avulsed fragment of the intercondylar eminence impinging upon the articular surfaces of the tibia and femur but results from muscle spasm. The avulsed fragment, although intra-articular, lies below the hollow of the intercondylar notch of the femur and does not interfere with motion of the tibia on the femur. In the child, no lateral instability is demonstrable even with the patient relaxed by anaesthesia. Anteroposterior instability is rarely present, and when present, is minor. Roentgenographic examination can reveal the fracture. It is necessary that clear anteroposterior and lateral views of the knee be

obtained. The fracture may be completely missed in the anteroposterior film when displacement is minor, but can always be detected in a good lateral roentgenogram. No specific roentgenographic views are necessary for diagnosis.

The intercondylar eminence of the tibia is a roughly triangular area with its base, anterior; and its apex, posterior. Posteriorly, near the apex of the triangle, it projects cephalad into the intercondylar notch to form the tibial spines. In late adolescence and adulthood, after complete ossification of the upper tibial epiphysis, its surface is cortical bone. Before completion of epiphyseal ossification, its surface is cartilaginous. The intercondylar eminence serves as an area for ligamentous attachments and does not at any time of life have a covering of articular cartilage. It does not articulate at any point with the gliding surface of either femoral condyle. The intercondylar eminence lies entirely beneath the hollow of the intercondyloid fossa of the femur and projects into more than adequate empty space.

FIG. 1

Roentgenogram of fracture of the intercondylar eminence of the tibia in a thirty-year-old adult with complete disruption of the medial collateral ligament of the knee joint.

The ligamentous ends of the medial and lateral menisci, along with the anterior cruciate ligament, insert into the intercondylar eminence (Fig. 2). The greater portion of the area of this eminence is covered by the insertion of the anterior cruciate ligament which fans out into a broad attachment with more of the ligament attached to the medial portion of the eminence which is larger than the lateral portion. The anterior ligamentous end of the medial meniscus inserts in front of the insertion of the anterior cruciate ligament near the anterior margin of the tibia. The anterior insertion of the lateral meniscus is posterior to the insertion of the anterior cruciate ligament. These insertions are separate and distinct and do not merge. Any individual insertion can be detached from the tibia without disturbing any other.

That the anterior cruciate ligament also contains large blood vessels can be

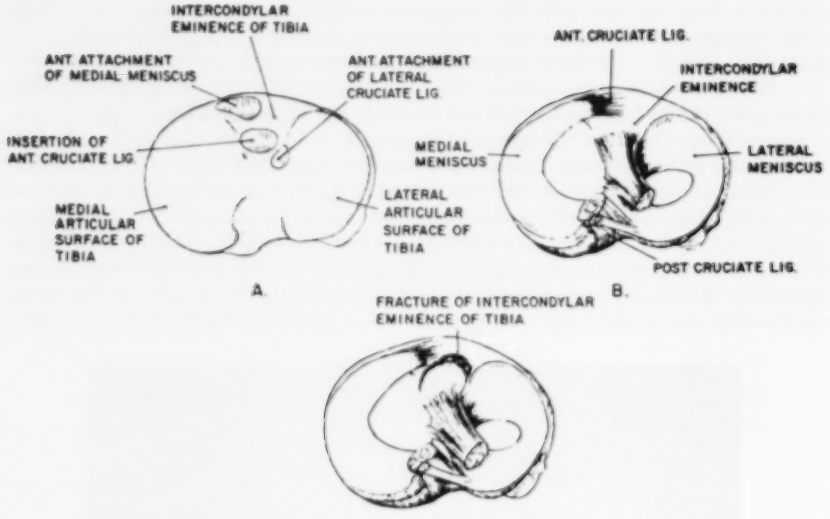

FIG. 2

Schematic drawing of, *A*, site of insertion of the anterior cruciate ligament, medial meniscus, and lateral meniscus into the intercondylar eminence of the tibia; *B*, relationship of the anterior cruciate ligament, medial meniscus, and lateral meniscus; and, *C*, fracture of the intercondylar eminence of the tibia and its relationship to the menisci.

easily demonstrated by microscopic sections. These blood vessels nourish any attached bone fragment; therefore, aseptic necrosis does not result in a bone fragment attached to this ligament. An avulsed fragment of bone dangling from the end of a cruciate ligament in a child may roentgenographically appear larger than actual size. The enlargement is due to maturation of epiphyseal cartilage contained in the detached fragment (Figs. 3-A and 3-B).

Functional studies of the knee joint [1,2] have established the fact that the anterior cruciate ligament is taut in extension and hyperextension of the knee and relaxed in the first portion of the arc of flexion, tightening again only as complete flexion is approached. The anterior cruciate ligament [4] acts as a deterrent to excessive internal rotation of the tibia on the femoral condyles. When violently forced internal rotation of the tibia occurs, severe strain is placed on the anterior cruciate ligament. Avulsion or complete absence of the anterior cruciate ligament, as an isolated lesion, with all other supporting structures of the knee intact causes no disabling instability of the knee joint. These facts are in keeping with the clinical findings present in a child during the acute stage of a fracture of the intercondylar eminence of the tibia which is, in essence, a detachment of the tibial insertion of the anterior cruciate ligament. The end results of this injury in children also verify these statements concerning the function of the anterior cruciate ligament.

CLASSIFICATION OF FRACTURES OF THE INTERCONDYLAR EMINENCE OF THE TIBIA

In this group of thirty-five children, three types of fractures of the intercondylar eminence of the tibia were seen. Type I, seen in ten patients, was the least severe. In this group, the avulsed fragment of bone was least displaced from its bed in the tibia. There was excellent bone apposition of the avulsed fragment with only slight elevation of its anterior margin. Type II had greater displacement; the anterior third to half of the avulsed fragment was elevated from its bone bed, producing a beaklike appearance in the lateral roentgenogram rather than the smooth rise of the normal intercondylar eminence. There were seventeen patients in this group. Patients with Type I and Type II fractures comprised 78 per cent

FIG. 3-A

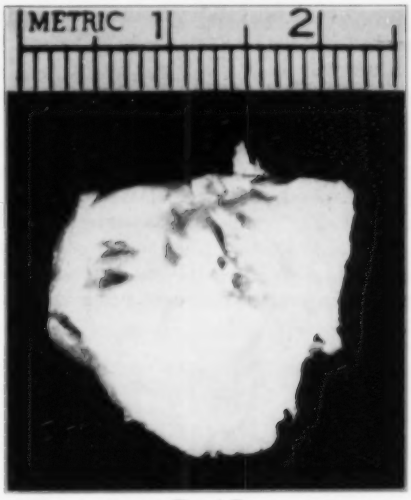

FIG. 3-B

Fig. 3-A: Roentgenogram of detached united fragment of the intercondylar eminence of the tibia removed eleven years after injury.
Fig. 3-B Photograph of the fragment.

of the series. There were eight patients with Type III fracture. In this group the avulsed fragment was completely lifted from its bone bed in the intercondylar eminence. The avulsed fragment was totally devoid of bone apposition and in some instances was rotated so that the cartilaginous surface of the avulsed fragment faced the bare bone of the eminence, making union of the fragment to the tibia impossible. The rotatory displacement of the avulsed fragment was similar to that seen after fracture of the capitellum of the humerus. It is extremely important that this group be recognized and properly treated (Figs. 4, 5-A, 5-B, 6-A, and 6-B).

TREATMENT

The treatment of fractures of the intercondylar eminence of the tibia as recommended in standard texts and in many reports on this fracture is not consistent with anatomical facts and with the end results of a simpler treatment. There is no logic in manipulating the knee into hyperextension with the patient anaesthetized. The fractured fragment is not between the articulating surface of the tibia and femur, but lies in an empty non-articulating area of the knee joint. Consequently, manipulation can neither dislodge the fragment nor can it more closely approximate the fragment to its bed. In no case in this series in which forceful manipulation was carried out was there conclusive roentgenographic evidence of an improved position of the avulsed fragment. Flexion deformity is due to muscle spasm; manipulation into extension releases this spasm but does not influence the position of the avulsed fragment. In hyperextension, the anterior cruciate ligament is made taut and put on stretch. Forceful manipulation into hyperextension may further displace the avulsed fragment attached to the distal end of the anterior cruciate ligament.

Treatment of Type I and Type II fracture should be simple. It should consist of aspiration of the hemarthrosis, when the joint is tense, followed by immobilization of the knee in a well fitting toe-to-groin cast. This cast should be applied with the knee in a comfortable, flexed position; no attempt to extend the knee beyond this comfortable position should be made. It is generally possible to apply this cast without the patient anaesthetized. Immobilization should be continued until there is roentgenographic evidence of healing of the fragment to its bed. This usually occurs in twelve weeks. When bone healing occurs, active exercises and weight-

bearing may be instituted. Within six weeks there is an excellent range of motion. Three months after the removal of the cast, normal motion in the knee and normal activity is the rule in a child.

The Type III fracture of the intercondylar eminence of the tibia, in which the avulsed fragment of the eminence is totally out of contact with its bone bed or rotated so that the cartilaginous surface of the fragment faces raw bone, requires open reduction. Once the diagnosis of Type III fracture has been made, there is no need to postpone open operation. Ten patients in the group of thirty-five children had arthrotomy. The operation was performed in one of these patients two months after injury, and in another five months after injury. Arthrotomy was performed on eight patients with Type III fracture and on two patients with Type II fractures in which the avulsed fragment still had contact with its bed of origin and did

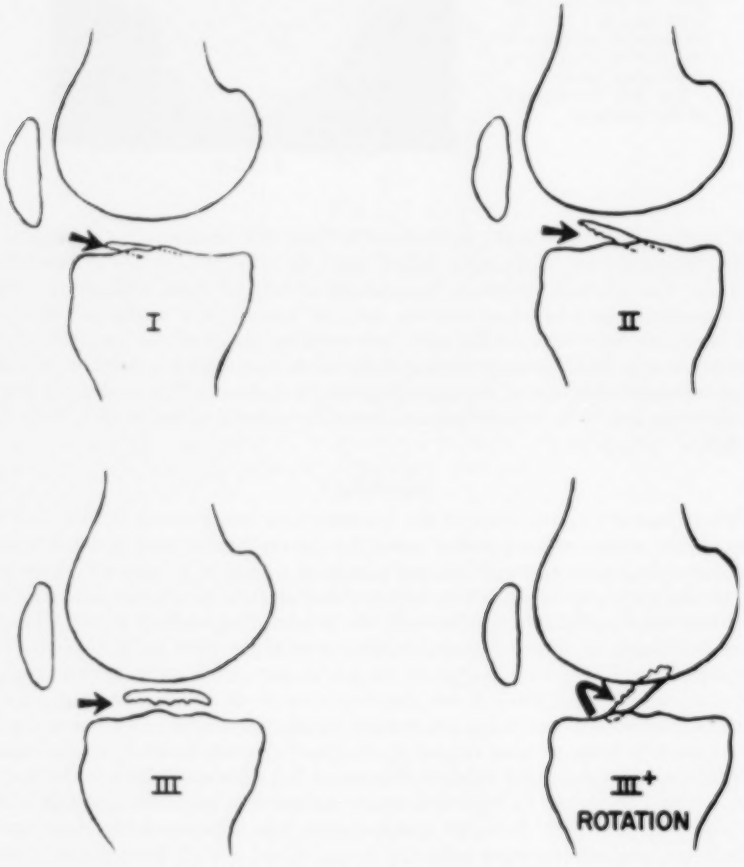

FIG. 4

Schematic drawing of the types of fractures of the intercondylar eminence of the tibia which occur in the child. Type I is the least severe. There is minimal displacement of the avulsed fragment and excellent bone apposition. Type II fracture, with displacement of the anterior third to half of the avulsed fragment from the intercondylar eminence, produces a beaklike deformity in the lateral roentgenogram. Type III fracture, in which the avulsed fragment is completely separated from its bone bed in the intercondylar eminence, has no apposition of the fragment. In Type III fracture, the avulsed fragment is completely lifted from its bone bed of origin in the intercondylar eminence and rotated so that the cartilaginous surface of the fragment faces the raw bone of the bone bed, making union impossible.

not require open reduction. In none, was other damage found in the knee joint. The anterior cruciate ligament and the attachments of the menisci were intact in all. In no instance did the medial meniscus prevent reduction. In only one knee was the avulsed area partially under the medial meniscus and in this instance it was easy to tuck the fragment under the sharp margin of the meniscus which aided in its retention. In eight patients the fragment was replaced in its bed. Metallic fixation, such as a screw or nail, is not necessary to retain the fragment. Nor is it necessary to drill a hole through the upper end of the tibia and pass a removable retention suture around the avulsed fragment to maintain its reduction. If retention is necessary, a simple absorbable suture (Fig. 7) passed through the thin edge of the avulsed fragment and through the meniscus near its sharp margin with a cutting needle will give adequate fixation. Six patients treated by open reduction had suturing done in this fashion, all with excellent results. The average follow-up

FIG. 5-A

Roentgenogram of Type I fracture of the intercondylar eminence of the tibia with displacement of the avulsed fragment.

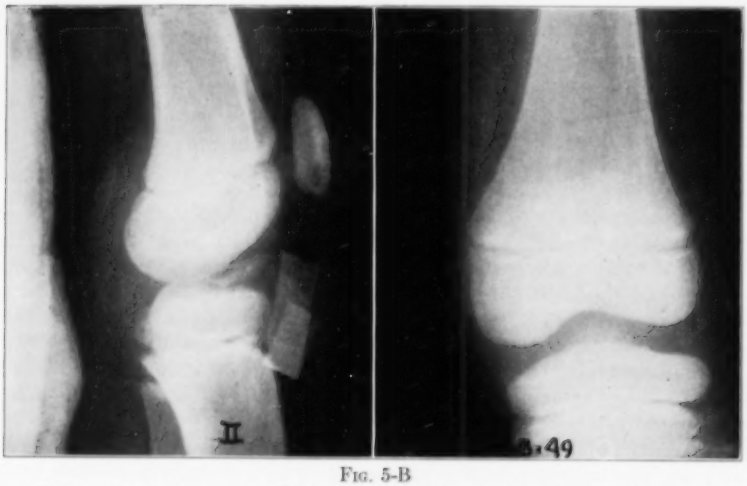

FIG. 5-B

The lateral roentgenogram of Type II fracture of the intercondylar eminence of the tibia with displacement of the anterior half of the avulsed fragment shows beaklike deformity.

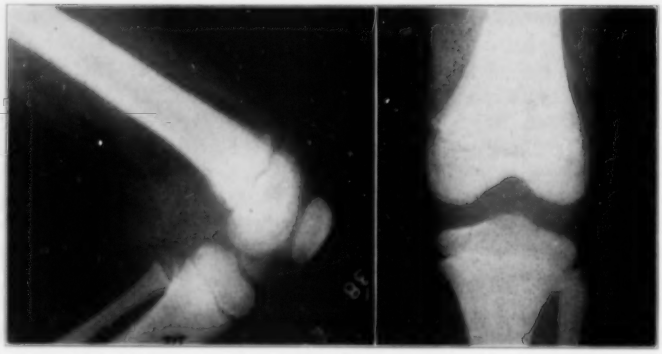

FIG. 6-A

Roentgenogram of Type III fracture of the intercondylar eminence of the tibia, in which the avulsed fragment is lifted entirely from its bed in the eminence. There is no bone apposition.

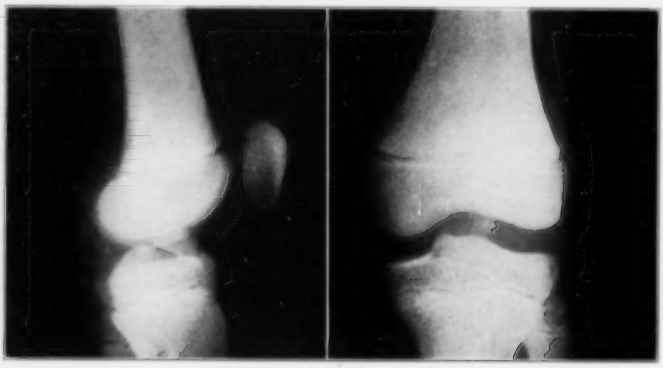

FIG. 6-B

Type III fracture of intercondylar eminence of the tibia, in which the completely displaced avulsed fragment has rotated so that its cartilaginous surface faces raw bone of the bed of origin.

period in five of the six patients was one year and nine months. One patient was followed for only a short time.

Following open reduction, the entire leg should be immobilized in a toe-to-groin cast with the knee joint in a comfortable, flexed position. Immobilization should be continued until there is roentgenographic evidence of bone union. These patients may require a longer period of immobilization than those in whom open reduction was not performed.

Late open reduction is possible. One child was not treated until five months after injury. This patient had persistent flexion deformity of the knee, pronounced atrophy of the thigh, and symptoms of locking. At the time of open reduction, the totally avulsed fragment dangled freely in the intercondylar notch and its bone surface was much altered, being covered by fibrous tissues. It was possible to refreshen the bone surface of the fragment and to replace it satisfactorily. The fragment united and the patient had normal motion in the knee. Four and one-half years after injury there was slight anteroposterior instability but the child had no complaints and was active.

Three patients had arthrotomy and excision of the avulsed fragment and the anterior cruciate ligament. In two, this was done as a primary procedure immediately after the injury. In one patient it was done eleven years after injury because of the presence of a loose body and persistent catching of the knee (Fig. 8). The

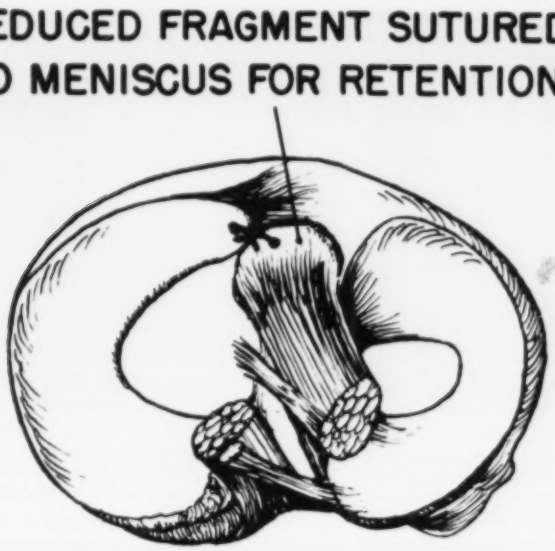

FIG. 7

Schematic drawing illustrating the use of an absorbable suture passed through the avulsed fragment and sharp edge of the meniscus. This is used for retention of the fragment in open reduction.

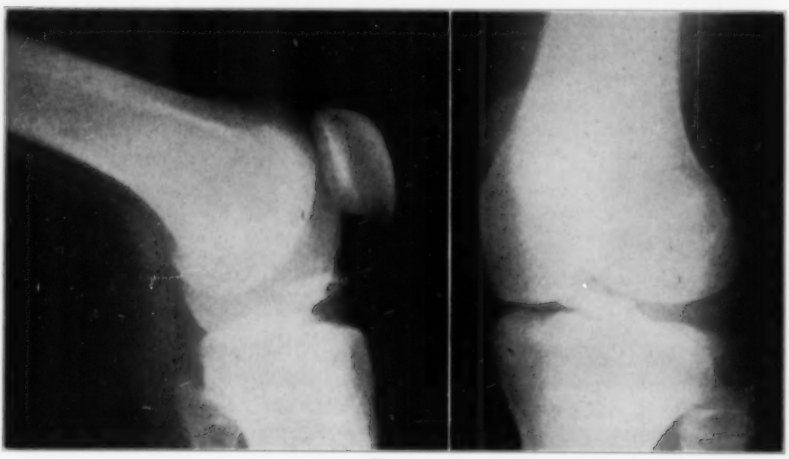

FIG. 8

Lateral and anteroposterior roentgenograms of ununited fracture of the intercondylar eminence of the tibia, with formation of a dangling loose body which caused symptoms of locking. The roentgenogram was made eleven years after injury.

two patients in whom arthrotomy was done as a primary procedure had no instability of the knee joint. The patient in whom the loose fragment was excised eleven years following injury had slight anteroposterior instability prior to the excision of the ligament and loose body. This slight "drawer sign" was not increased. This is clinical evidence that the anterior cruciate ligament of the knee can be removed without leading to instability, providing all other supporting structures are intact. Routine excision of the avulsed fragment and detached anterior cruciate ligament in Type III fracture of the intercondylar eminence does not seem justified, since open reduction is simple and the results uniformly good. It is impossible to be cer-

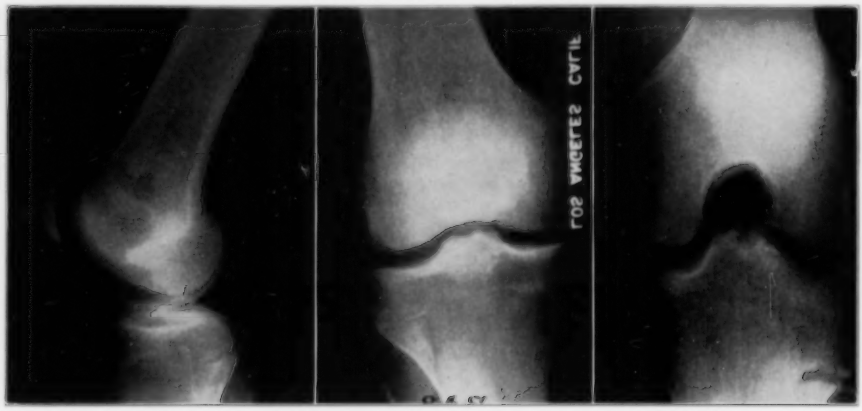

FIG. 9

Lateral, anteroposterior, and postero-anterior roentgenograms twenty years after Type II fracture of the intercondylar eminence of the tibia when the patient was a child. There is a mild cephalic bulge of the spines of the tibia. The knee joint is normal and the patient has continuously engaged in strenuous athletics without difficulty.

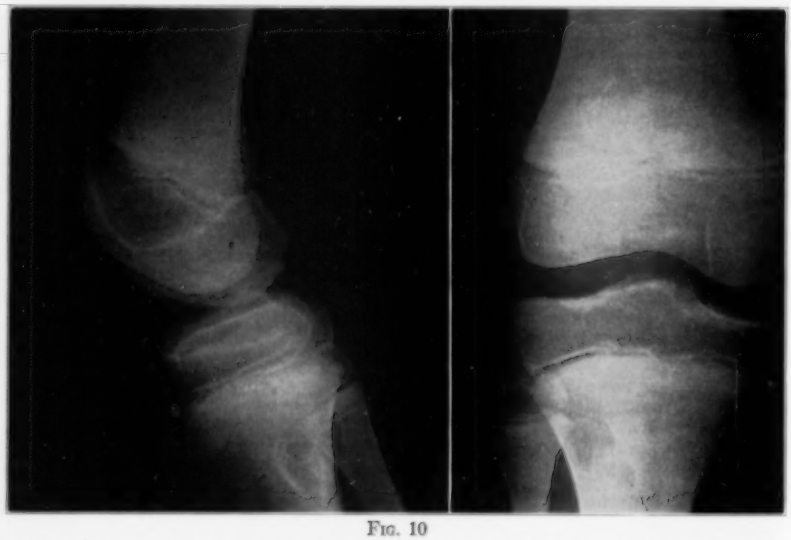

FIG. 10

Lateral and anteroposterior roentgenograms of Type I fracture of the intercondylar eminence of the tibia of a child made four years after injury. The child's knee joint is normal.

tain that there may not have been some injury to other supporting ligaments or that the knee, deprived of its anterior cruciate ligament, may not more easily suffer a severe ligamentous injury from trauma which would not damage it if all ligaments were present.

COMPLICATIONS

One child with Type III fracture of the intercondylar eminence of the tibia was treated by simple immobilization rather than open reduction. Non-union developed with a large loose body, persistent catching and locking, and effusion in the knee joint. The detached fragment increased due to the blood supply it received through the anterior cruciate ligament and to maturation of epiphyseal cartilage in the fragment. Eleven years after injury, arthrotomy was done. It was

FIG. 11

Lateral and anteroposterior roentgenograms of Type II fracture of the intercondylar eminence of the tibia in a child, three years after injury. There is beaklike deformity of the eminence but the knee joint is normal.

impossible to reattach the fragment due to attenuation of its shape and surfaces and to scarring of the bed from which it had been avulsed. The fragment was removed with the anterior cruciate ligament. The patient, two years later, had normal motion in the knee with no symptomatic instability. There was slight, detectable increase in anteroposterior mobility of the tibia on the femur.

END RESULTS

Of the thirty-five children in this series it was possible to determine the end result in thirty-three. Twenty-five of the twenty-seven patients with Type I and Type II fractures had an excellent result, with normal motion and normal stability, and no limitation of activity. One patient with Type II fracture had very slight anteroposterior instability; the result was classified *good*. The result in one was unknown. It was possible to evaluate, twenty years after injury, one patient who had Type II fracture (Fig. 9). This patient had a normal knee joint, even though roentgenograms revealed roughening and abnormal cephalic projection of the intercondylar eminence and spines. This individual now leads a vigorous life and had participated in intercollegiate sports. No patient with either Type I or Type II fracture had a poor result. The final roentgenogram, after healing, showed some degree of cephalic bulge of the intercondylar eminence and spine in all patients. This in no way influenced the function of the knee (Figs. 10 and 11).

Of the eight patients with Type III fracture, in which there was complete dislodgement of the avulsed fragment, five had an excellent result. One had a good result, with normal motion and only slight anteroposterior instability of the tibia on the femur. One patient who was not treated by open reduction had a poor result due to failure of the fragment to unite and the formation of a loose body which dangled from the anterior cruciate ligament. This was the direct result of poorly elected treatment. This patient was much improved by excision of the loose body and the anterior cruciate ligament. In one patient, the end result was not known (Table II).

CONCLUSIONS

1. Fracture of the intercondylar eminence of the tibia, although not a common fracture, occurs more frequently in children than adults. Its greatest incidence is between the ages of eight and thirteen.

TABLE II

END RESULTS IN FORTY-FIVE PATIENTS
Classified by Type of Fracture and Treatment in Thirty-five Children

	Excellent	Good	Poor	Unknown
Adults (10)	2	1	7	0
Children (35)	30	2	1*	2
Type I fracture	9	0	0	1
Type II fracture	16	1	0	0
Type III fracture	5	1	1	1
Treatment				
Immobilization	22	0	1‡	1
Arthrotomy and reduction	6	1	0	1
Excision of fragment	2	1	0	0

*Due to non-union and formation of a loose body.

‡Good result after removal of ununited fragment (Type III fracture) eleven years after injury.

2. In children, this fracture occurs as an isolated injury without damage to the other supporting ligaments or gliding surfaces of the knee joint; the prognosis for complete recovery without difficulty is excellent.

3. In adults, fracture of the intercondylar eminence of the tibia is so often accompanied by serious injury to the supporting structures of the knee or other bone injury that serious permanent disability often results.

4. Fractures of the intercondylar eminence of the tibia in children may be divided into three types as demonstrated by roentgenograms: Type I, in which there is no dislodgment of the fragment from its bed of origin; Type II, in which there is partial dislodgment of the fragment, but still good apposition of a large portion of the avulsed fragment; and Type III, in which there is complete dislodgment of the avulsed fragment from its bed and no bone apposition of the fragment.

5. Type I and Type II fractures of the intercondylar eminence of the tibia require only immobilization for a length of time adequate to allow bone union. Open reduction is not indicated in Type I and Type II fractures.

6. Forceful manipulation of the knee into hyperextension with the patient under anaesthesia is not indicated.

7. Type III fracture of the intercondylar eminence of the tibia with complete dislodgment of the fragment requires open reduction followed by immobilization.

8. Elaborate metallic internal fixation of the fragment is not required.

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DISCUSSION

DR. CARLO SCUDERI, CHICAGO, ILLINOIS: The cases have been well studied over a long period of time, and I don't think that there is any disagreement about the treatment. I was fascinated by the accurate description of the condition that exists in these fractures which heretofore was not clear to me; I think that because of this lack of knowledge I will now have to revise several procedures I have done in the past.

I saw two children with marked avulsion of the eminence. At that time, I did not know that it was possible to hold the fragment in place with a simple catgut suture to the meniscus; but certainly, I am going to try that in the future. In both of these patients I removed the

eminence completely and the children, as far as I could determine after following them for several years, had excellent end results. I believe that this is due to little or no associated pathological condition in the knee joint seen in adults with fracture and displacement. I have had substantial experience with fractures of this type in adults and the results have been satisfactory. I believe that the authors brought out the point that the associated pathological condition is extensive in many adult patients.

I have made every attempt possible to reattach the eminence by various methods. I finally decided on the pull-out stainless-steel wire as the best method of holding the fragment during the healing period. However, none of the methods tried left me with a great deal of enthusiasm. This method is the best that we have and I feel that, in adults, every attempt should be made to reattach the fragment by firm fixation. I don't feel that catgut suturing alone will hold the fragment to the meniscus.

We have had experience with some patients who underwent other procedures. I think I have probably seen two or three patients who had congenital or complete absence of the anterior cruciate ligament; yet, these people have excellent knee joints. About fifteen or eighteen years ago, Cubbins published a rather extensive and comprehensive article on reconstruction of the cruciate ligaments. I was interested in this phase of the subject and felt that if it is just a torn cruciate ligament the result will be a good knee. If there are other structures torn, then of course, reconstruction of the cruciate ligament, even if done successfully, will yield a disabled knee with loss of flexion. I agree with the authors here that Type I and Type II fractures should be treated conservatively. If I ever see any more Type III fractures, I intend to follow the sound principles that the authors advocate.

DR. O. SHERWIN STAPLES, HANOVER, NEW HAMPSHIRE: This presentation is of considerable clinical value since it offers important information to a surgeon facing one of these relatively rare injuries. The authors' classification of fractures of the intercondylar eminence of the tibia, correlated with a treatment program provides practical guidance, particularly when backed by the thorough end-result study of the patients treated.

In children, I am especially interested in the results of Type II fracture with displacement but incomplete separation of the fragment of the intercondylar eminence. In the past, we operated on two children with such injuries, I believe, now, unnecessarily. I do not disagree with the study as presented or with the conclusions or recommendations proposed. The number of patients treated and studied is impressive and constitutes an experience much wider than mine.

Of particular interest to me was the prognosis of adults compared with children with this injury, brought out by end-result study. The results in the young with proper treatment were uniformly good or excellent, and, in adults, none was good. It was well pointed out that not only more violence is required to produce fractures of the intercondylar eminence in adults, but that other damage to the injured joints was common, making the problem more complex. I should like to ask Dr. Meyers what forms of treatment he would recommend in the adult group and whether he has suggestions to improve the results in this group.

In the past five years we have treated four adults with fracture of the intercondylar eminence of the tibia, and our end results all have agreed with those given today. Our main problem of treatment was not instability, but much stability, since restoration of joint motion and function was uniformly long and difficult and permanently impaired in three of the four patients. One of the patients also had minimal fractures of the tibial and femoral condyles and of the fibular head along with partial avulsion of the medial collateral ligament. The others had no major ligament or bone damage but did have a marked degree of synovial tissue and joint damage. One patient later showed, by roentgenogram, a moderate degree of calcification in the infrapatellar fat pad; another exhibited numerous intra-articular adhesions largely filling the intercondylar notch noted at operation six months after injury.

The last adult patient treated for this injury by us had Type III fracture with complete separation of a large portion of the intercondylar eminence of the tibia and no additional major injury except for marked contusion of the synovial tissues. In this patient we attempted to gain early motion by securing the fragment to its bed by a heavy stainless-steel wire inserted almost completely extra-articularly. By using balance splints, both active and passive motion was attempted on the twelfth postoperative day, but because of the persistent synovitis and joint tenderness, a minimum was accomplished until one month after operation. One year later with bone union and no deformity, only 60 degrees of motion was present starting from full knee extension, although the knee was strong and only occasionally painful. Slow gain in flexion was apparently being made. If faced with this problem again, it occurred to me that possibly a short course of meticorten, beginning perhaps one week postoperatively might lessen joint reaction and pain enough to allow an earlier start at restoration of function providing, of course, that the fracture could be securely fixed and no other major injuries were present. I should like to know Dr. Meyers' reaction to this idea.

DR. MEYERS (closing): In answer to many questions, we removed the anterior cruciate

ligament in three children with no instability demonstrable after several years. We feel, however, that the fragment should be replaced because it is an added safeguard for the future in the event serious injury should occur again. We had four adult patients who had an associated complete tear of the medial collateral ligament, and we feel that this is the more serious injury. It should be repaired.

I can offer no suggestions for improving the results in adults. As far as hydrocortisone is concerned, I don't know. When we remove a torn meniscus, hydrocortisone injected into the joint following surgery seems to decrease morbidity in these patients. It would be interesting to see what it does in fracture of the intercondylar eminence.

DISCUSSION

The Phasic Activity of the Muscles of the Lower Extremity

(Continued from page 208)

taneous motion. They concluded that the ability of the individual to learn to use the biceps transfer properly was based on changes in higher centers which were able to override the innate coordinative associations without abolishing them.

In 1938 Peabody, reporting on tendon transfers, gave as the end result of eighteen cases of biceps transfer to the patella: normal control—eleven; improved—six; failure—one. On the basis of past experience, transfer of the hamstrings to the patella, to replace a weak or paralyzed quadriceps muscle in carefully selected patients, is a sound operative procedure and may be expected to give satisfactory results.

Dr. Close is testing the function of muscles in the automatic activity of walking, and, as pointed out by Weiss and Brown, under such circumstances, even an educated muscle may relapse into its former activity. Despite these findings I feel sure we will continue to use this form of tendon transfer, but, as pointed out by Crego a long time ago, we should probably spend more time with postoperative education.

In regard to using extensors for extensor replacement, and flexors for flexor replacement, Dr. Close has shown, with the aid of a laboratory instrument, facts that have been well established from clinical observation. His findings in regard to the peronaei, I think, are interesting in that the peronaeus brevis is much more apt to change its phase of activity than the peronaeus longus, and therefore should work better than the peronaeus longus when transferred to the dorsum of the foot. I was not aware of this, nor have I found this in the literature. Peabody, in 1938, found that when the peronaeus longus was transferred to the dorsum of the foot, drop-foot was corrected in nineteen out of twenty patients. When one or both peronaei were transferred to the dorsum of the foot, the results of fifty-one out of fifty-four were satisfactory. He apparently did not note any particular difference in the two peronaei. In addition, he felt that transfer of the tibialis anterior to the calcaneus was the only transfer that restored a heel-to-toe gait or allowed tip-toe support. Two of the seven such transfers examined by Dr. Close showed conversion of their phasic activity. Peabody further expressed the opinion that transfers, or a combination of transfers, using extensor and flexor muscles, did not perform better than single transfers. This corresponds to Dr. Close's finding.

The indications, methods, and results that may be expected of tendon transfer are on a sound clinical basis. Since the results of tendon transfer as evaluated by electromyography are not always the same, I do not believe that preoperative electromyographic studies can be of much prognostic significance. It does point out two interesting facts: (1) Where there is a choice between the peronaeus longus and brevis, perhaps it would be better to transplant the peronaeus brevis to the dorsum of the foot for drop-foot. However, Steindler and others have cautioned against removing the brevis. (2) It re-emphasizes that combining flexors and extensors to replace either lost flexion or extension activity gains nothing over using the available flexor for flexor loss, or extensor for extensor loss. It seems to me that this method of study is much more important in the postoperative stage as a test of the effectiveness of our re-educational program.

Dr. Melvin R. Krohn, Cleveland, Ohio: We studied, electromyographically, sixty-nine transplantations done last year at the Newington Home and Hospital for Crippled Children

(Continued on page 235)

Surgery in the Treatment of Low-Back Pain and Sciatica*

A Follow-up Study

BY FRED C. REYNOLDS, M.D., A. E. MCGINNIS, M.D., AND HARRY C. MORGAN, M.D.,
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Previous evaluation, based on information obtained by questionnaires, of the results of disc surgery performed in our department indicated that the results in 450 cases were: good in 82 per cent, fair in 6.9 per cent, and poor in 11.1 per cent [1,2,3,4,5]. These patients were treated in an era in which we were rather prone to operate, and the results, while not ideal, were sufficiently good to warrant continuation of that philosophy. However, as time went on we seemed to see more and more patients in the postoperative periods who either failed to obtain complete relief or had recurrence of their symptoms. Memory of those disappointing cases, together with a better understanding of the pathological physiology and natural history of disc degeneration, caused us to adopt an extremely conservative attitude toward low-back pain, with or without sciatica. It seemed advisable, therefore, that we redefine our indications and contra-indications for surgery in patients with symptomatic degenerated disc, with or without evidence of nerve-root compression. To accomplish this, it was necessary to review the literature and restudy our patients.

In spite of the fact that the patient's evaluation of his result is of the utmost importance, it seemed that more reliable information could be obtained by personal re-examination of the patient and new roentgenograms. To reduce the variables as much as possible only patients operated on by a single surgeon, Reynolds, at a single hospital, during the years 1946 to 1952, were selected.

The uncontrollable variables were:

1. The hospital records and a description of the operative findings had been recorded by different members of the house staff.

2. In many instances, the original roentgenograms and myelograms had been discarded and therefore were not available for review. In these cases, we had to rely upon the written reports and our own recorded interpretation of the films.

3. We were able to obtain follow-up examination on only 115 of the 205 patients operated upon during the six-year period. This may tip the results toward the unfavorable side; the patient still having trouble may be more prone to return for re-examination.

4. A comparable group of patients on whom a clinical diagnosis of ruptured disc was made, but who were treated conservatively, are not available for re-examination.

Analysis of the 115 patients who did return for re-examination forms the basis for this report.

Proper management of low-back pain and sciatica, by whatever method, requires understanding of past experience as well as current concept. The literature on this subject is so voluminous that discussion is impossible in this paper. In fact, it is impractical to include a complete bibliography. However, a review of the papers written has contributed to our present attitudes.

* Aided by a grant from the United States Public Health Service.

TABLE I

EXCELLENT RESULTS AFTER A SINGLE OPERATION—12

Male	9				
Female	3				
Average age	43.4 yrs. (oldest, 60; youngest, 29)				
History of injury	5				
Average postoperative time in hospital	10.8 days				
Average time, return to work 2 mos.	13 days				
Average follow-up	7 yrs.				
Duration of symptoms, before operation	3.3 yrs.				
Medicolegal	0				
Type of Pain					
Back pain only	0				
Sciatica only	0				
Low-back pain and unilateral sciatica	10				
Low-back pain and bilateral sciatica	2				
		Reflex	Motor	Sensory	
Preoperative neurological changes		8	2	7	
Postoperative neurological changes		5	1	1	
Normal to abnormal	0				
Abnormal to normal	4				
Normal before and after	2				
Abnormal before and after	6				
Myelograms	5				
Positive, correlated with positive operation	5				
Positive, but different location at operation	0				
Negative correlated with negative operation	0				
Negative, but positive operative findings	0				
Type of Disc Removed		Extruded	Bulging	Degenerated	Normal	Total
		6	8	2	0	16
Location of Disc Removed		L3	L4	L5		
		0	8	8		
Multiple discs removed	4					
Spine fusion	1 (Pseudarthrosis)					
		Same	Opposite	Bilateral		
Sacralization, 5th lumbar transverse process		0	0	1		
Pars interarticularis defect—bilateral	1					
Spondylolisthesis	0					
Anaesthesia		Local	General			
		12	0			
Complications	0					
Operation Contra-indicated		Degenerated Disc		Functional		
		1		0		

In addition to the final grade assigned each case, we were anxious to determine what factor, or factors, might influence the grading. It seemed to us that the following questions were pertinent: (1) The relationship of the patient's age to the result? (2) Was there a sex difference? (3) Did the duration of preoperative or postoperative symptoms and disability influence the final rating? (4) Were those patients who had a definite history of injury more apt to have a good result than those who did not? (5) How did the compensation cases compare with the non-medicolegal cases? (6) How accurate were the myelograms? (7) Did the location of the disc removed or the pathology of the disc influence the end result? (8) What was the effect of spine fusion? (9) Was there anything, neurologically, either before or after operation, of prognostic value?

To facilitate study and classification, cases were grouped under the headings of: *excellent*, *good*, *fair*, and *poor*. The criteria established for this grouping are as follows:

TABLE II

GOOD RESULTS AFTER A SINGLE OPERATION—32

Male	22					
Female	10					
Average age	39.6	yrs. (oldest, 62; youngest, 19)				
History of injury	14					
Average postoperative time in hospital	10.8	days				
Average time, return to work	4.2	mos.				
Average follow-up	7.33	yrs.				
Duration of symptoms before operation	4.8	yrs.				
Medicolegal	4					
Type of Pain						
Back pain only	1					
Sciatica only	1					
Low-back pain and unilateral sciatica	27					
Low-back pain and bilateral sciatica	3					
			Reflex	Motor	Sensory	
Preoperative neurological changes			19	6	12	
Postoperative neurological changes			19	3	6	
Normal to abnormal	6					
Abnormal to normal	7					
Normal before and after	4					
Abnormal before and after	15					
Myelograms	15					
Positive, correlated with positive operation	11					
Positive, but different location at operation	1					
Negative, correlated negative operative finding	3					
Negative, but positive operative findings	0					
Type of Disc Removed		Extruded	Bulging	Degenerated	Normal	Total
		13	21	5	0	39
Location of Disc Removed		L3	L4	L5	Bilateral	
		2	15	21	1	
Multiple discs removed	7					
Spine fusion	4	(2 Pseudarthrosis)				
		Same	Opposite	Bilateral		
Sacralization, 5th lumbar transverse process		1	0	0		
Pars interarticularis defect		1		2		
Spondylolisthesis	1	Fusion—Solid				
Anaesthesia		Local	General	Not indicated		
		29	2	1		
Complications	1	Hematoma				
Operation Contra-indicated		Degenerated Disc		Functional		
		4		0		

1. For a result to be considered *excellent* a patient must have been able to return to his former occupation and to have remained completely free of pain. In addition, he must not have significant neurological deficit.

2. For a result to be considered *good*, a patient must have been able to return to his former occupation and to have had no periods of disability since the operation, although he may have had one or two episodes of slight pain in the back or leg. He must not have significant neurological deficit.

3. For a result to be considered *fair*, a patient must have been able to return to his former occupation, but he may have suffered pain in the back or leg from

TABLE III

FAIR RESULTS AFTER A SINGLE OPERATION—26

Male	16					
Female	10					
Average age	39.8 yrs. (oldest, 60; youngest, 22)					
History of injury	14					
Average postoperative time in hospital	12.3 days					
Average time, return to work	6.1 mos.					
Average follow-up	7.16 yrs.					
Duration of symptoms before operation	3.1 yrs.					
Medicolegal	8					
Type of Pain						
Back pain only	1					
Sciatica only	0					
Low-back pain and unilateral sciatica	20					
Low-back pain and bilateral sciatica	5					
		Reflex	Motor	Sensory		
Preoperative neurological changes		6	7	9		
Postoperative neurological changes		12	4	4		
Normal to abnormal	3					
Abnormal to normal	5					
Normal before and after	7					
Abnormal before and after	11					
Myelograms	18					
Positive, correlated with positive operation	12	Discogram 1				
Positive, but different location at operation	3					
Negative, correlated negative operative findings	2					
Negative, but positive operative findings	1					
Type of Disc Removed		Extruded	Bulging	Degenerated	Normal	Total
		8	18	4	0	30
Location of Disc Removed		L3	L4	L5		
		1	21	8		
Multiple discs removed	3					
Spine fusion	0					
Sacralization, 5th lumbar transverse process	0					
Pars interarticularis defect	0					
Spondylolisthesis	0					
Anaesthesia		Local	General			
		25	1			
Complications; 1 infection, 1 toxic psychosis						
Operation Contra-indicated		Degenerated Disc		Functional		
		6		0		

time to time or may have short episodes of pain requiring bed-rest. He may have had, on examination, weakness, sensory loss, or atrophy of a mild degree.

4. All other results were classed *poor*.

In addition, the results in all of the patients who had more than one operative procedure were classed *poor* for the first operation. It appears to us that this grading is rather severe, and that in all probability the results of all patients in the excellent, good, and fair groups should be considered satisfactory.

Using the above criteria for grading, we have for those operated upon only once twelve patients with results classed *excellent;* thirty-two, *good;* twenty-six, *fair;* and forty-five, *poor*. Twenty-seven of the forty-five patients whose results were classed *poor* had two or more operative procedures, with subsequent

TABLE IV

POOR RESULTS AFTER A SINGLE OPERATION—18

Male	6	
Female	12	
Average age	44.2	yrs. (oldest, 60; youngest, 19)
History of injury	6	
Average postoperative time in hospital	13.4	days
Average time, return to work	11.2	mos.
Average follow-up	7.4	yrs.
Duration of symptoms before operation	7.9	yrs.
Medicolegal	3	

Type of Pain

Back pain only	1	
Sciatica only	1	
Low-back pain and unilateral sciatica	14	
Low-back pain and bilateral sciatica	2	

	Reflex	Motor	Sensory
Preoperative neurological changes	0	6	6
Postoperative neurological changes	4	2	7

Normal to abnormal	5	
Abnormal to normal	2	
Normal before and after	5	
Abnormal before and after	5	(1 inadequate information)
Myelograms	13	
Positive, correlated with positive operation	7	
Positive, but different location at operation	1	(elsewhere—1)
Negative, correlated with negative operation	2	
Negative, but positive operative findings	2	
Positive, with negative findings	1	

Type of Disc Removed	Extruded	Bulging	Degenerated	Normal	Total
	4	13	6	0	23

Location of Disc Removed	L3	L4	L5
	1	14	8

Multiple discs removed	6	
Spine fusion	1	Pseudarthrosis

	Same	Opposite	Bilateral
Sacralization, 5th lumbar transverse process	1	1	2

Pars interarticularis defect	0	
Spondylolisthesis	0	
Anaesthesia		

Local	General	Not indicated
17	0	1

Complications 1 hematoma 1 peroneal palsy 1 disc removed 1 infection

Operation Contra-indicated	Degenerated Disc	Functional
	5	6

change in the final classification in nineteen. The over-all final classification is then: thirteen, *excellent;* forty, *good;* thirty-six, *fair;* and twenty-six, *poor.*

Anteroposterior, lateral, and right and left oblique roentgenograms of the lumbosacral spine were made of each patient. All showed evidence of narrowing of one or more disc spaces and varying degrees of other degenerative changes.

These changes, including alteration of the posterior articulations, could not be correlated with the results and therefore are not singled out for discussion. In many patients the operative defect was still clearly visible, while in others it was difficult to tell the level or side operated upon. In a number of patients a portion of the contrast medium (pantopaque) was not recovered at the time of myelography.

TABLE V

PATIENTS WITH MULTIPLE OPERATIONS—27
FIRST OPERATION—25
(2 had first operation elsewhere)

Male	17					
Female	8					
Average age	41.3 yrs. (oldest, 55; youngest, 30)					
History of injury	16					
Average postoperative time in hospital	11 days					
Average time, return to work	8.2 mos.					
Average follow-up	7.5 yrs.					
Duration of symptoms, before first operation	4.4 yrs.					
Medicolegal	5					
Type of Pain						
Back pain only	1					
Sciatica only	0					
Low-back pain and unilateral sciatica	19					
Low-back pain and bilateral sciatica	4					
		Reflex	Motor	Sensory		
Preoperative neurological changes		14	5	16		
Postoperative neurological changes		9	3	11		
Normal to abnormal	3					
Abnormal to normal	5					
Normal before and after	2					
Abnormal before and after	14					
Myelograms	12	1 Discogram				
Positive, correlated with positive operation	8					
Positive, but different location at operation	2					
Negative, correlated negative operative findings	0					
Negative, but positive operative findings	2					
Type of Disc Removed		Extruded	Bulging	Degenerated	Normal	Total
		4	24	2	0	30
Location of Disc Removed		L3	L4	L5		
		1	15	14		
Multiple discs removed	5					
Spine fusion	0					
Sacralization, 5th lumbar transverse process	0					
Pars interarticularis defect	0					
Spondylolisthesis	0					
Anaesthesia		Local	General			
		24	0			
Complications	1 infection	1 damaged root	1 talc granuloma	1 foreign body		
Operation Contra-indicated		Degenerated Disc		Functional		
		5		0		

Many of these underwent roentgenographic examination following this procedure in order to show the amount of dye retained. Comparison of these with the newest follow-up roentgenograms revealed that where a considerable quantity of pantopaque had been retained, it was still present, although in lesser amounts, as long as seven or eight years afterwards. Late roentgenograms revealed complete disappearance of the pantopaque in most patients where the quantity retained immediately following the myelogram was small. Other roentgenographic findings, such as spondylolisthesis, spondylichisis, and sacralization of the transverse processes are recorded in the tables.

TABLE VI

PATIENTS WITH MULTIPLE OPERATIONS—27
SECOND OPERATION—24
(3 had second operation elsewhere)

Male	15				
Female	9				
Average age	43.1	yrs. (oldest, 55; youngest, 30)			
Average postoperative time in hospital	14.1	days			
Average time, return to work	8.3	mos.			
Average time between 1st and 2nd operation	24.08	mos. (longest, 93 mos.; shortest, 3 mos.)			
Average follow-up	7.5	yrs.			
Medicolegal	5				
Type of Pain					
Back pain only	5				
Sciatica only	1				
Low-back pain and unilateral sciatica	10				
Low-back pain and bilateral sciatica	2				
			Reflex	Motor	Sensory
Preoperative neurological changes			10	3	12
Postoperative neurological changes			11	5	9
Normal to abnormal	3				
Abnormal to normal	4				
Normal before and after	3				
Abnormal before and after	14				
Myelograms	13				
Positive, correlated with positive operation	9				
Positive, but different location at operation	1				
Negative, correlated with negative operation	1				
Negative, but positive operative findings	2				
Type of Disc Removed		Extruded	Bulging	Degenerated	Normal	Total
		8	12	4	0	24
Location of Disc Removed		L3	L4	L5		
		0	17	7		
Multiple discs removed	5					
Spine fusion	10	(8 solid—2 pseudarthrosis)				
Spine fusion without disc excision	4					
Sacralization, 5th lumbar transverse process	0					
Pars interarticularis defect	0					
Spondylolisthesis	0					
Anaesthesia			Local	General		
			10	14		
Complications Talc granuloma 1		Excision sinus tract 1				
Operation Contra-indicated		Degenerated Disc		Functional		
		0		0		

To conserve space, data pertinent to each group are recorded in table form. Of the eighty-eight patients who had but a single operation, the results in twelve were graded *excellent* (Table I); thirty-two, *good* (Table II); twenty-six, *fair* (Table III); and eighteen, *poor* (Table IV).

Study of the twenty-seven patients who required more than one operation (Table V) reveals that two had the first operation performed elsewhere. Data in Table V refer therefore to the first operation performed on only twenty-five patients, as we were unable to obtain information on the two who were operated on

TABLE VII

PATIENTS WITH MULTIPLE OPERATIONS
Third Operation—5

Male	4				
Female	1				
Average age	43.2 yrs. (oldest, 49; youngest, 36)				
Average postoperative time in hospital	15 days				
Average time, return to work	10.6 mos.				
Average follow-up	4.35 yrs.				
Average time between 2nd and 3rd operation	16.4 mos. (longest, 26 mos.; shortest, 2 mos.)				
Medicolegal	3				
Type of Pain					
Back pain only	4				
Sciatica only	0				
Low-back pain and unilateral sciatica	1				
Low-back pain and bilateral sciatica	0				
		Reflex	Motor	Sensory	
Preoperative neurological changes		3	2	1	
Postoperative neurological changes		4	2	2	
Normal to abnormal	1				
Abnormal to normal	1				
Normal before and after	0				
Abnormal before and after	3				
Myelograms	1				
Positive, correlated with positive operation	1				
Positive, but different location at operation	0				
Negative, correlated with negative operation	0				
Negative, but positive operative findings	0				
Type of Disc Removed		Extruded	Bulging	Degenerated	Normal	Total
		1				1
Location of Disc Removed		L3	L4	L5		
			1			
Multiple discs removed	0					
Spine fusion only	3 (3 solid—0 Pseudarthrosis)					
Sacralization, 5th lumbar transverse process	0					
Pars interarticularis defect	0					
Spondylolisthesis	0					
Anaesthesia		Local	General			
		1	4			
Complications	1 root sectioned	1 infection persisted				
Operation Contra-indicated		Degenerated Disc		Functional		
		0		0		

at other hospitals. While the results in these patients are all considered failures, careful study of the records and patients indicates a contra-indication to the operative procedure in only five. On the other hand, operation was considered unnecessary in eleven of the eighteen patients in the single operation group whose results were graded *poor*.

Fourteen patients who had multiple operations performed were free of symptoms for varying periods of time after the initial operation. Ten patients had recurrence on the original side; three of these were apparently brought on by new injuries. The longest period of time in which a patient was free of symptoms before

TABLE VIII

RESULTS FROM REOPERATION—27

	Excellent	Good	Fair	Poor
After second operation	0	7	7	7
After third operation	1	0	3	1
After fourth operation	0	1	0	0
Total	1	8	10	8
Spine fusion 13	1	4	5	3 (2 pseudarthroses)
No fusion 14	0	3	5	6

TABLE IX

LOCATION OF DISC AND NUMBER OF OPERATIONS ACCORDING TO SEX

Females — 45

L3			L3 and L4			L3 and L5			L4			L4 and L5			L5			Bilateral
R	M	L	R	M	L	R	M	L	R	M	L	R	M	L	R	M	L	L5
0	0	0	0	0	0	0	0	0	17	1	15	2	0	7	2	0	4	1

Number of operations for removal of disc tissue 52
Number of disc spaces operated upon 59
Disc tissue removed from 4th lumbar space 42

Males — 70

L3			L3 and L4			L3 and L5			L4			L4 and L5			L5			Bilateral
R	M	L	R	M	L	R	M	L	R	M	L	R	M	L	R	M	L	L4
2	0	0	1	1	0	0	0	1	16	1	12	8	0	8	15	1	17	1

Number of operations for removal of disc tissue 82
Number of disc spaces operated upon 104
Disc tissue removed from 4th lumbar space 47
Disc tissue removed from 5th lumbar space 49

TABLE X

CORRELATION OF PREOPERATIVE FINDINGS WITH RESULTS IN THE SINGLE OPERATION GROUP—88

	Excellent	Good	Fair	Poor
Clear-cut history, physical or myelographic findings or both	7	15	9	4
Atypical preoperative findings	5	17	17	14

recurrence on the same side was five years and two months; the shortest period was two months. Four additional patients were free of pain for varying intervals of time before they had recurrence on the opposite side; two of these apparently had new injuries. The longest period of time in which a patient was free of symptoms was seven years and five months; the shortest period was one month. The remaining thirteen patients did not obtain relief of pain following the first operation.

Analysis of the second operation performed on these twenty-seven patients reveals that three were done at another hospital, or by a different surgeon, and were therefore not included. Table VI refers to the second operation in the multiple operation group.

Five patients, four men and one woman, underwent a third operation (Table VII). Three were compensation cases. One myelogram was made; this was posi-

tive and correlated with positive operative findings. This patient had had a spine fusion done in conjunction with the second operation but it was not solid. Exploration through the semifused area revealed an extruded disc at the fourth lumbar space. Three patients had spine fusions performed without exploration of the intervertebral-disc spaces; these appear solid. The other patient in this group had a sinus tract excised.

One patient had a fourth operation performed; an excision of the sinus tract persisting from the previous operation. This was successful and the patient's final result was graded *good*.

Table VIII shows the grades after each operative procedure and the final classification in this group of patients who had multiple operations performed. Also, the patients on whom spine fusion was done with secondary procedures are compared with those who did not undergo spine fusion.

DISCUSSION

Before attempting to answer the questions mentioned previously, all data were submitted to statistical analysis by the method of t tables. The studies revealed:

1. There was no correlation between the age of the patient and the result.

2. The results of twenty-one of the forty-five females were poor; ten patients required reoperation. In twenty-four of the seventy males the results were poor; seventeen required reoperation. This would suggest that there is a greater chance of having a poor result in a female than in a male. Although our clinical impression bears this out, statistically there was no significant difference.

Fifty-seven operative procedures (fifty-two of which were associated with the removal of disc tissue at fifty-nine disc spaces) were carried out on the forty-five female patients (Table IX). Two operations were for the removal of a foreign body and an attempt at eradication of an infected wound. Two operations were spine fusions without disc removal. Two additional patients had their first operation and one the second operation performed elsewhere.

In the female patients, no disc material was removed from the third lumbar space. Material was removed from the fourth space thirty-three times; from both the fourth and fifth spaces, nine times; and from the fifth space alone, seven times. One of these was bilateral. Twenty-two were on the right side, twenty-seven on the left, and one was mid-line. We are sure others were mid-line, but were probably not described as such due to a unilateral approach.

Further study of these figures reveals that in the female patients disc material was removed from the fourth lumbar space in forty-two of the fifty-nine spaces entered. We were not aware of this preponderance in women of involvement of the fourth space. Should these figures be substantiated in a larger series of cases, it may be that the structure of the female pelvis is responsible for the high incidence of degenerative changes in the fourth lumbar disc.

Eighty-two operations for the removal of disc material in 104 spaces were performed on the seventy males (Table IX). Two patients had discs removed from the third space alone; two from the third and fourth spaces; and one from the third and fifth spaces. Material was removed from the fourth lumbar space alone in thirty patients (one bilateral); from the fourth and fifth lumbar spaces in sixteen; and from the fifth lumbar space alone in thirty-three. There is no characteristic pattern in males.

3. In those patients whose results were classed *excellent*, the average preoperative duration of symptoms was three years and four months, while in those whose results were classed *poor* the average preoperative duration of symptoms was seven years and eleven months. Despite this difference, statistical analysis indicates that in prognosis the duration of symptoms alone is not significant.

4. Fifty-five of the 115 patients gave a history of injury, while sixty did not. Again, no significance can be attached to these figures.

5. Twenty patients had medicolegal involvement. The literature, as well as our own experience, indicates that compensation cases do not do as well after disc surgery as do those patients who have no medicolegal problems. We find in our grading that there are no compensation cases whose results were excellent; there are four with good results, eight with fair, and eight with poor results. Again, when these figures are submitted to statistical analysis, one can see that there is no significant difference in the chances of a compensation case obtaining a satisfactory result, providing all patients with results classed *excellent*, *good*, and *fair* are considered satisfactory.

6. We were quite interested in determining the accuracy of our preoperative myelograms and also in determining whether or not the myelogram would materially influence the end results. For the entire series, seventy-seven patients (66.9 per cent) had myelograms made by us. Of these, sixty-one (79.2 per cent) were completely accurate. Fifty-three were positive and correlated with positive operative findings; eight were negative and correlated with negative explorations. Eight other myelograms were positive, but the operative findings (although positive) revealed the abnormal disc located at a different level from that indicated by the myelogram. Seven negative myelograms were associated with positive operative findings. Ten myelograms revealed double defects, and double abnormal discs were found.

Analysis reveals that the performance of the myelogram did not lessen or increase the chances of a satisfactory result. However, here again we see that, in the patient whose results were graded *excellent* and *good*, accuracy is almost 100 per cent, indicating that better results may be expected when the myelogram definitely indicates a disc type of defect. At the present time, it is rare not to perform myelography before operation. Two patients had discograms made; the finding in each was degeneration of the disc.

7. Of the 115 cases, thirty patients had more than one disc removed. Five discs were removed from the third lumbar interspace, ninety-one from the fourth, and sixty-seven from the fifth. Description of the discs removed indicated that forty-four were completely extruded; ninety-six, bulging; and twenty-three, degenerated. In the eighty-eight patients making up the single operation group, six of the patients whose results were excellent, thirteen with good results, and eight with fair results had extruded discs, while only four extruded discs were found in the eighteen patients whose results were classed *poor*. Analysis of the pathology of the disc reveals that there is a significantly greater chance of a satisfactory result if the patient has a completely extruded disc.

8. Only six patients had spine fusion, combined with removal of disc tissue, performed at the first operation. There was only one patient in whom a ruptured disc was associated with spondylolisthesis. Spine fusion was carried out at the time of this removal. There were three patients with bilateral, and one patient with unilateral, pars interarticularis defect without displacement. Spine fusions were also performed on these patients at the time of operation. In all of these, bone-bank bone was added, and four failed to fuse. These failures did not seem to influence the result, as one failure was in the excellent group, two in the good, and only one in the poor. At the time of subsequent operations, thirteen patients had spine fusion (Table VIII), following which the result in one patient's grade was raised to *excellent;* the results in four, to *good;* in five, to *fair;* and in three, the results remained *poor*. Two of these three patients had pseudarthrosis.

9. In the single operation group, preoperative neurological examination showed that there were reflex changes in eight of the twelve patients in whom results were classed *excellent;* in nineteen of the thirty-two whose results were classed *good;* in six of the twenty-six whose results were classed *fair;* and none in the eighteen whose results were graded *poor*. This is a significant finding and corresponds to our impression, clinically, that those patients with definite abnormal results at neurological examination show, as a rule, a more accurate location

of the lesion and a more extensively diseased disc. Evaluation of the results comparing patients with clear-cut preoperative findings with those with meager or atypical findings (Table X) shows a steady decrease in the number of patients with positive findings as one goes down the scale. However, if we add to the poor classification the results of twenty-seven patients on whom more than one operation was performed, then the figures for neurological changes are not significant.

Neither the length of stay at the hospital nor the duration of postoperative disability was significantly correlated with the end result. It is our opinion that the operation was probably not indicated in twenty-eight (24.3 per cent) of the patients; twenty-one because of disc degeneration without rupture, six because of functional disturbances, and one patient who was later found to have rheumatoid spondylitis. The results of twelve of these patients fall into the satisfactory range in spite of the operation rather than because of it.

There were 145 operative procedures carried out on the 115 patients, 134 associated with the removal of disc tissue. Five operations were done elsewhere. Local anaesthesia was used 118 times, and general anaesthesia twenty-three times; in two patients, the type of anaesthesia is not recorded. The average stay at the hospital was 11.6 days; the average postoperative follow-up was 7.3 years. Sacralization of the fifth lumbar transverse process was present in six patients; two had unilateral sacralization on the same side as the pain, one had unilateral sacralization on the opposite side from the pain, and three had bilateral sacralization.

Addition of the patients on whom multiple procedures were done to the total gives a final classification of results of thirteen *excellent*, forty *good*, thirty-six *fair*, and twenty-six *poor*. If we accept as satisfactory results all those graded *excellent*, *good*, and *fair*, we have 77.39 satisfactory and 22.61 per cent unsatisfactory results. (Previously reported results in 450 patients who were followed by questionnaire only are: good in 82 per cent, fair in 6.9 per cent, and poor in 11.1 per cent.) It would appear that either this group of patients happens to encompass more unsatisfactory results or the method of study is more objective. However, as only 115 of the 205 patients operated on were available for study, we have a small sampling, which may influence the figures. We do not feel that this small sampling would influence our opinion of the 115 cases we were able to study.

CONCLUSIONS

We have submitted the records of 115 patients operated upon for intervertebral-disc lesion to a rather searching analysis. The results in these patients have been classified according to arbitrarily established criteria and as many variables as possible were eliminated from the study. In addition, the figures were all submitted to statistical analysis. Significant findings are:

1. Patients with good historical, physical, and myelographic evidence of nerve-root compression obtain better results from disc surgery.

2. Patients who, at operation, are found to have completely extruded discs obtain better results.

3. In this series, the results in women are not significantly worse than in men.

4. In women, the majority of disc lesions are located at the fourth lumbar interspace. Many of these were also associated with degenerative discs at the fifth lumbar interspace.

5. In men, there appears to be no such predilection for any given interspace.

6. Fourteen (12 per cent) of the patients had recurrence; ten of these were on the same side as the original lesion, and four were on the opposite side.

7. Twenty-eight patients (24.3 per cent) probably should not have had an operation performed.

It seems clear that if we remember the past history of low-back pain and sciatica and if we understand the pathological changes in the disc with the resulting altered function of the disc unit, we will limit surgery to those who continue

to be disabled as a result of pain, or have progressive neurological alteration in spite of adequate conservative therapy. At the present time, it is our opinion that where conservative treatment fails and after careful study exploration reveals only a degenerated disc, spine fusion should be done. In those cases in which the operative finding is one of definite nerve-root compression, simple disc excision seems adequate. When the original operation fails or the patient has recurrence, fusion should be a part of the secondary operative procedure.

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DISCUSSION

The Phasic Activity of the Muscles of the Lower Extremity

(Continued from page 222)

and our results are almost identical with Dr. Close's. In transplantation of the peronaeus longus to the dorsum of the foot, we got only three results; three transplantations that were actually converted out of twenty-two converted from the stance-phase to the swing-phase activity.

We had 50 per cent good clinical results, but eight of the good clinical results were very poor electromyographically because, although the patient had excellent voluntary control of his muscle he did not convert the phase at all in the automatic function of walking.

The other type of transplantation where phase activity must be changed is the tibialis anterior to the heel. We had only three cases; the muscles in two of these three patients converted their activity from a swing phase of the normal tibialis anterior to stance-phase activity after the transplantation.

Dr. Wallace Duncan, Cleveland, Ohio: I would like to ask Dr. Close if he can explain the discrepancy between his findings which are, of course, very exact and absolute and those of the University of California group who pointed out that the tibialis anterior, for example, was primarily a late swing, early heel-strike muscle. This seems to be quite a wide divergence of opinion. Also, in their integrated recordings, the hamstrings were considered late swing-phase muscles.

Dr. Close (closing): In almost every case that I can remember where mixed transfers are used there the non-phasic transfer fails. I think that answers Dr. Reynolds' question.

Concerning Dr. Duncan's question about the tibialis anterior acting late and about the hamstrings acting late, this is a matter of individual variation, I believe. If I had shown you a hundred rather than one, it would have been much more complicated, but I could show you that variation.

The Bankart Shoulder Reconstruction

The Use of Pull-out Wires and Other Practical Details

BY PETER VIEK, M.D., AND BEN T. BELL, M.D., BRYN MAWR, PENNSYLVANIA

Every conscientious surgeon searches to find the one operation which will correct, permanently and effectively, a given pathological condition. In the instance of recurrent dislocation of the shoulder, that search has been extensive, probably spanning centuries. In modern times at least sixty operations, so-called solutions to this baffling and disabling problem, have been reported. No single structure about the shoulder joint has been immune from surgical attack. The various operations might be classified under the following categories: (1) capsular reefing, (2) bone block, (3) new check ligaments, and (4) repair of the glenoid rim.

No attempt will be made to evaluate the merits of these types of repair—a recent paper by Rowe does so commendably—since it is now well established by both American and British surgeons that repair of the glenoid rim is the most reliable. This explains the increase in popularity of the Bankart procedure which was first described in 1923, but was not generally accepted for various reasons. In the first place, Bankart admitted that he kept no follow-up records of his work and surgeons were asked to accept his word without statistical evidence of success. He unfortunately wrote very little and did not publish another paper, again without statistics, until 1938, fifteen years after the original one. Orthopaedic surgeons of insight could also not accept his dogma of the essential glenolabral lesion. Platt stated in 1945 that ". . . there was no single and constant 'Bankartian' lesion capable of being repaired by a standard procedure. . . ." DePalma, in fact, reported that the essential lesion is associated with advancing age rather than with trauma since he found it in many apparently normal autopsy specimens. His impression of the underlying pathological cause in recurrent dislocation is laxity of the musculotendinous cuff which is never present in normal shoulders. Finally, the Bankart procedure itself, as originally de-

FIG. 1

Position of the patient on the operating table and manner of draping. The head and neck are draped during surgery.

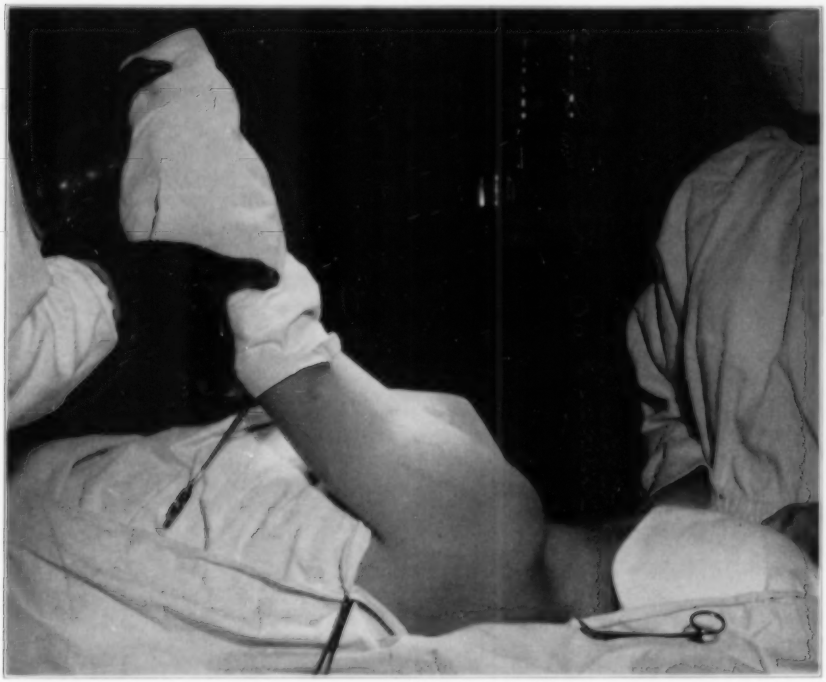

FIG. 2-A

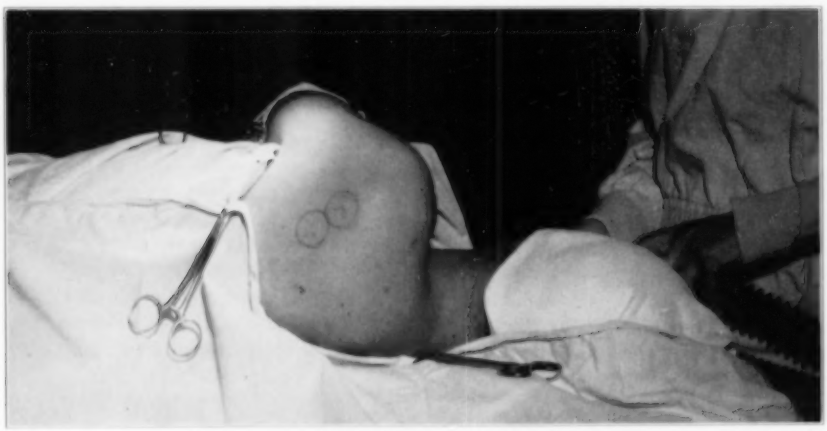

FIG. 2-B

Figs. 2-A and 2-B: Manipulation of the right shoulder during surgery.

scribed, is a difficult and time-consuming one. Therefore, many attempts at short cuts or simplification have been made.

TECHNIQUE

We have been convinced by the extensive reported experience that the Bankart reconstruction is highly reliable—over 95 per cent, in fact. It and its equally reliable counterpart, the Putti-Platt procedure, have virtually displaced all other operations. The Royal Air Force, for example, between 1940 and 1945 switched to these procedures to the exclusion of others. We have personally used

the Bankart operation exclusively in the last ten years in thirty-nine instances (Table I). However, we have modified it somewhat, as suggested by Watson-Jones [23], to include double-breasting and shortening of the subscapularis in the manner of Putti-Platt. During this period only one redislocation occurred; one patient fell about eight weeks after the procedure causing sufficient trauma to result in a fresh dislocation. He was treated as if the dislocation were an original one, and at the time of writing (one year later) has not had recurrence. We have found it valuable to shorten the subscapularis and occasionally to insert the proximal end of the distal portion of this muscle into the freshened glenoid rim, especially in those patients in whom the glenoid is abnormally shallow. This deformity may be due to repeated trauma but is probably due to a congenital

TABLE I

FOLLOW-UP EVALUATION OF OPERATIVE PROCEDURE (39 Patients)

Follow-up *(Years)*	No Recurrence *(No. of Patients)*	Recurrence *(No. of Patients)*
10	1	
7	1	
6	2	
5	12	
4	12	
3	6	1
2	2	
1	2	
Totals	38	1

anomaly. In our experience this shallowness is usually bilateral. Attaching the proximal end of the distal part of the subscapularis to the glenoid rim is also of value in those instances where the capsule is markedly attenuated or damaged in the course of exposure.

TECHNICAL DETAILS

Rowe, by recently stating that the difficulties of the Bankart procedure are somewhat overemphasized and that the technical steps may be eased with proper instruments, positioning, and adequate assistance, has expressed our own feelings. The technical steps we follow are:

1. Preparation of the patient is extended to the axilla and posterior aspect of the scapula and upper portion of the thorax.

2. Sterile drapes, consisting of a rubber sheet and overlying double-thickness sheets, are placed under the thorax to allow manipulation of the shoulder so that the scapula can be exposed aseptically. The arm is then draped separately also to allow manipulation.

3. A sandbag placed under the affected side props the patient's thorax up at a 30 to 45-degree angle (Fig. 1).

4. The upper portion of the Henry exposure [11] is utilized and the anterior circumflex veins are ligated at the lower border of the subscapularis.

5. After the coracoid is sectioned by an osteotome, the subscapularis is dissected from the capsule and the capsule is divided at the rim of the glenoid. We have encountered the glenolabral defect in the usual percentage of our patients (about 80 per cent) but have been struck by the frequent occurrence (5 per cent) of a shallow glenoid [8].

6. In order to visualize the joint and the immediate periarticular structures, the dislocating head must be kept out of the way. This is best accomplished by an assistant whose sole function is to manipulate the shoulder, throughout the operation, from the vantage point of the wrist, thus being well out of the sur-

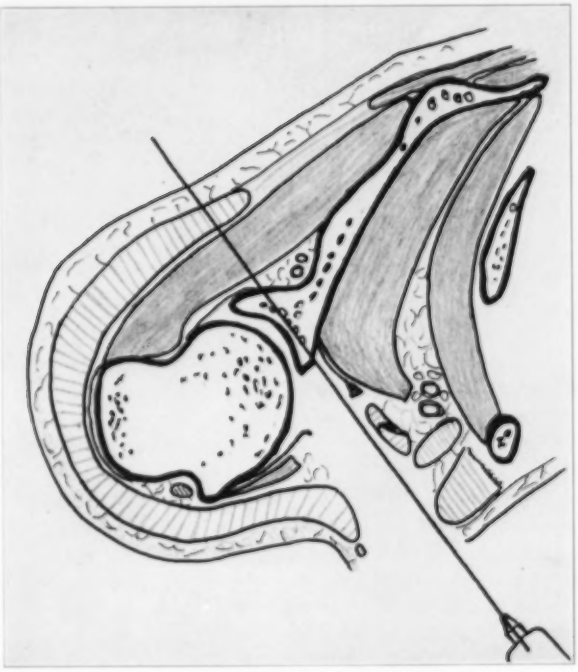

FIG. 3-A

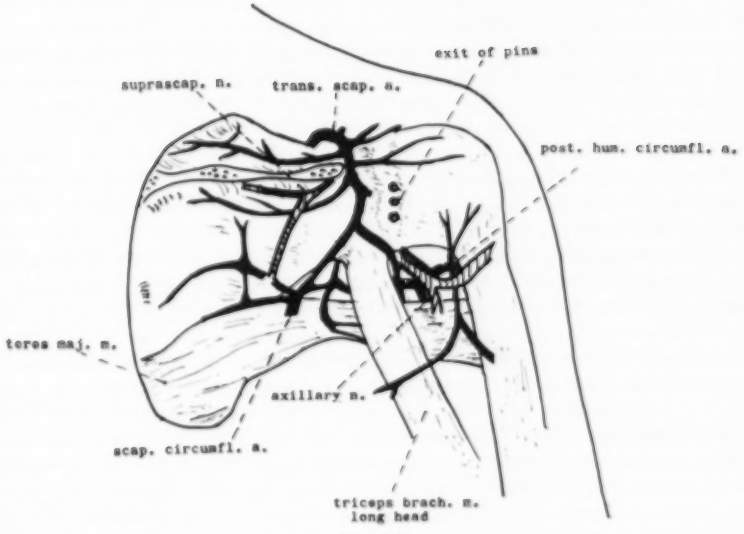

FIG. 3-B

Figs. 3-A and 3-B: The Steinmann pins pass through the glenoid rim emerging laterally to the suprascapular nerve and the transverse scapular artery.

geon's way. The humerus is held in internal rotation and some flexion (Figs. 2-A and 2-B).

7. In addition, the humeral head is depressed by means of the Bankart retractor held down on the neck or wedged between the posterior rim of the gleniod and head, prying the two apart.

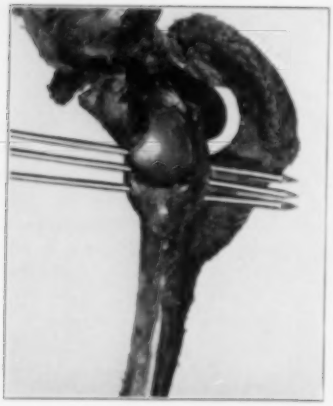

FIG. 4-A

FIG. 4-B

Steinmann pins in an autopsy specimen to demonstrate the location of the drill holes.

8. The anterior glenoid rim and neck of the scapula are then denuded of cortex and roughened with an osteotome, a small gouge, and a mallet.

9. At this point, we abandoned the original Bankart procedure of stitches through the remaining articular cartilage; this was awkward and caused unavoidable damage to articular cartilage. The step of attachment of capsule to freshened bone was thought to be crucial by Bankart. Various surgeons have attempted to simplify this step by the use of metal, such as staples [20] or plates [14], or by making bridges in the neck of the scapula. Eyre-Brook described one of these bridges to be ". . . sufficient tax on the operator . . ." and felt that loose or detached staples and plates are poor neighbors to axillary structures. Bankart stated that any means of fixation is only temporary: "In this operation union is complete in six weeks or less, after which the fixing agent has done its work and might just as well not be there. Indeed, the less there is of it the better." We feel that our variation is the ideal answer to this demand. When recovery is complete, not even silk sutures are retained near the joint. Three one-eighth of an inch drill holes are made antero-inferiorly through the freshened scapular neck in a backward, upward, and slightly outward direction (Figs. 3-A through 4-B). They emerge at a point just below the base of the outer part of the scapular spine, then penetrate the infraspinatus and deltoid muscles and the skin. It is important to keep the direction slightly lateral in order to avoid injury to the suprascapular nerve and the transverse scapular artery.

10. Braided wire (00) sutures are next placed in the detached labrum, capsule, or proximal end of the distal portion of the scapularis, as the case may be, in such a position that when the four ends of these sutures are pulled through the drill holes from before backward, the new capsule will be held against the denuded area on the glenoid rim and scapular neck. These sutures are tightened and the scapular skin exposed. Before tying them, the effectiveness of the pull-out wires should be tested by pulling on them anteriorly. The capsular sutures are then tied tightly over two buttons in the manner of Bunnell.

11. The wire sutures, each with a pull-out wire in place, are passed through the drill holes (Fig. 5) by means of three one-eighth of an inch Steinmann pins. The ends of the sutures are threaded through the eyes of the Steinmann pins which are in turn pushed through the drill holes in the scapula and out through the overlying skin of the back with the shoulder held in full adduction (Fig. 2-B).

12. The incision is closed by overlapping of the remaining capsular structures using chromic 1 sutures and fastening the proximal portion of the subscapu-

FIG. 5

Lateral roentgenogram made postoperatively shows the humerus in adduction and internal rotation. The anterior pull-out wires to the labral sutures are not under tension. The labral sutures are seen to be in the antero-inferior aspect of the glenoid rim which is the usual location of the lesion. The middle drill hole shares the lower loop of the upper suture and the upper loop of the lower suture.

laris to the periosteum of the lateral crest of the bicipital groove. This method frequently allows external rotation to a maximum of 30 degrees. We personally agree with Watson-Jones [21,22,23] and Osmond-Clarke regarding the value of limited external rotation, particularly in those disturbing instances where a glenoid labrum cannot be refashioned. Our patients have not objected to this limitation, and indeed are grateful for its presence, having acquired a conscious fear of external rotation in the past.

13. From the moment the wire sutures are tied, the assistant holds the humerus in constant internal rotation and adduction. After operation this position is maintained by the Velpeau dressing.

14. The pull-out sutures are tied loosely over the buttons anteriorly. With subsidence of operative oedema, capsular sutures may be tightened by twisting the scapular buttons. The pull-out sutures are removed about three to four weeks after surgery.

15. Active motion is allowed six weeks after operation. There is little blood loss with this operation and in spite of the extensive exposure, the patient has surprisingly little discomfort postoperatively. We make a definite point of graduated resistance exercises of the shoulder girdle with dumbbells or similar appliances for an indefinite period thereafter. A useful range of motion is acquired within two to three weeks (90 degrees abduction, 100 degrees flexion and 5 to 10 degrees external rotation). A full range of motion except for limitation of external rotation is usually achieved within two to three months.

SUMMARY AND DISCUSSION

The pull-out wire technique for suturing tendons and ligamentous structures was originally described by Bunnell. Its application to the present problem has been carried out by the authors since 1947. A comparable method, used for two years, was described in 1949 by Luckey who had operated on fifteen patients. After similar exposure, Luckey preserved and divided the capsule and sutured its lateral end to the freshened glenoid rim with a No. 24 or No. 26 gauge steel wire. He employed only one pull-out stitch through two drill holes and did not attempt to repair the labrum in any instance nor did he shorten the subscapularis. He reported no recurrence after follow-ups of one to two years. The method reported here, therefore, is by no means original. We prefer the use of braided wire because of its great tensile strength and the ease with which it can be handled. We use large coat buttons in tying the sutures. The steps described, we believe, are not sufficiently different from Bankart's technique to incur his disapproval. We have, like him, never attempted to show the defect in the humeral head and have trusted our repair to overcome the increased tendency to recurrence that it causes when present. The essential points of our technique are then: (1) adequate assistance and positioning; (2) use of the Bankart retractor; (3) attachment of the glenoid labrum, the capsule or lateral subscapularis or both to the freshened neck by means of two Bunnell braided wire pull-out sutures; (4) shortening of subscapularis; (5) postoperative fixation and resistance exercises.

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Recurrent Congenital Club-Foot

The Role of the M. Tibialis Posterior in Etiology and Treatment

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The treatment of congenital club-foot is started soon after birth. Different types of correction are used, and the feet may be immobilized in splints or plaster [7]. Club-foot recurs in many of these feet after inadequate initial treatment or poor after-care; even with good treatment some unsatisfactory results are encountered, the incidence being reported as high as 25 per cent [3]. Treatment of the recurrence is more difficult than primary treatment with the result that conservative procedures very often lead to unsatisfactory results, and surgery is finally required for correction. The many methods used for surgical correction indicate how difficult it may be to solve the problem of this deformity [5,8,9,10,12,14]. Any procedure used for surgical correction should be based on the pathological anatomy of the deformity. This paper is intended to point out the main factors responsible for recurrence and to describe the method of correction based on the pathological condition found in each of the treated patients.

GENERAL CONSIDERATION

The cause of club-foot is uncertain. Recent experimental work [4] suggests that abnormal biochemical processes may play some role since Duraiswami was able to induce a comparable deformity by injecting chicken embryos with insulin.

Many authors have looked for the underlying structural cause of the deformity. Stillborn babies with club-foot have been dissected [2,14]. Anomalies of soft tissue and bone have been described. According to these observations, it seems obvious that anomalous tendon insertions, particularly those of the tibialis anterior, triceps surae, and short plantar muscles, contribute to the development of the deformity. The osseous changes seem more or less secondary to these, hence correction at an early age may prevent the development of bone abnormalities.

PATHOLOGY

An analysis of patients with club-foot reveals three main components of the deformity: varus of the heel, equinus of the ankle, and adduction of the fore part of the foot. If the nature of these components is to be explained by muscle anomalies, such as pathological muscle pull or contractures of muscle and tendon structures, then there is only one muscle the contraction of which can produce all three manifestations of the deformity. The tibialis posterior, arising from the posterior aspects of the interosseous membrane, tibia, and fibula, inserts after its tendon passes behind the medial malleolus into the tuberosity of the navicular with fibrous extensions from here to the cuneiform bones and medial metatarsal bones (Fig. 1). Its function is combined and its contraction produces, in the normal foot, a position not unlike that of club-foot as shown (Fig. 2) in the leg of a stillborn baby where the tendon of the tibialis posterior was exposed in the lower portion of the leg and a strong pull exerted on it.

It is evident that overaction or contracture of the tibialis posterior is not the only abnormality present. The severe equinus deformity and the regular occurrence of extensor weakness in patients with club-foot show that overaction or contracture of the triceps surae is always present in addition to the pathological condition of the tibialis posterior. A further finding is weakness of the peroneal

FIG. 1

FIG. 2

Fig. 1: Normal insertion of the tendon of the tibialis posterior in the foot of a stillborn baby.

Fig. 2: Pulling on the tendon of the tibialis posterior above the medial malleolus in a normal foot produces club-foot.

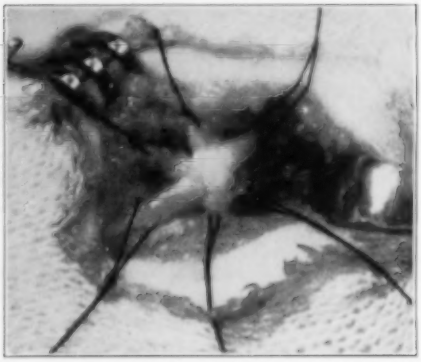

FIG. 3-A

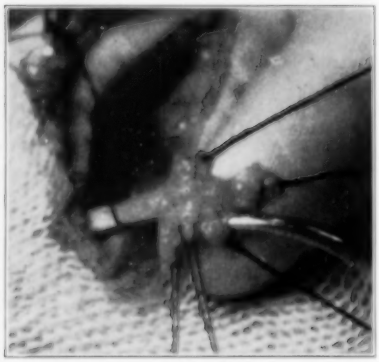

FIG. 3-B

Tendon of the tibialis posterior in a case of recurrent club-foot. The tendon shows typical fibrosis and expansion of fibrous bands: before (Fig. 3-A) and after (Fig. 3-B) separation from insertion.

muscles and evertors of the foot. It would seem that in club-foot the available muscle power is shifted, partly at least, from the anterior and lateral to the medial and posterior aspect of the leg. Skeletal deformities of the foot increase with growth if deformity persists. Correction of the deformity, obtained by conservative means or by soft-tissue surgery in many cases suggests that skeletal deformity is secondary and reversible.

The anomalies of the tibialis posterior in patients with club-foot are seldom mentioned in the literature [11,13]. Because it was assumed that this muscle is one of the main pathological causes of club-foot, it was dissected out carefully in fifty-six feet between 1953 and 1957. Two of these feet had had no previous treatment at any time before operation.

It was surprising to find similar changes in the tendon of this muscle in all the feet explored. The tendon was thickened, sometimes as thick as an Achilles tendon in a normal child of the same age. The tendon was found to lose its tendinous appearance and shiny surface at the level of the tip of the medial malleolus. At this point the tendon was found to change to a thick, hard fibrous mass which encompassed the whole medial side of the tarsus sending thick strands of fibrous tissue to other parts of the foot; namely to the cruciate ligament, plantar fascia, deep plantar ligaments, os calcis, scaphoid, tendon of the tibialis anterior, and bones of the mid-portion of the foot. At least six strands were always found (Figs. 3-A through 5). This fact was often responsible for the difficulty encoun-

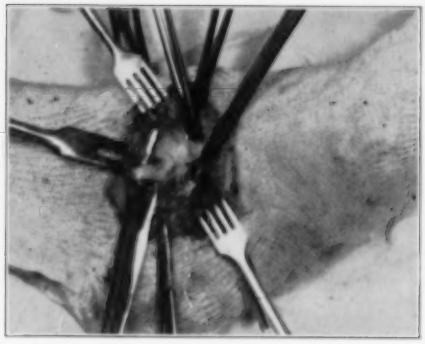

FIG. 4-A

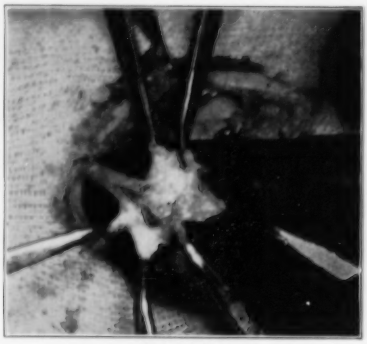

FIG. 4-B

Insertion of the tendon of the tibialis posterior in recurrent club-foot. Same findings as those described in Figs. 3-A and 3-B.

FIG. 5

Schematic drawing of the common findings in cases of recurrent club-foot showing fibrous thickening of the tendon and fibrous strands extending from the tendon to the medial, plantar, and dorsal regions of the foot.

tered in locating the tendon of the tibialis posterior at the mid-portion of the foot distal to the medial malleolus.

In summarizing these findings, it should be noted that in club-foot the tibialis posterior has a thickened tendon which shows fibrosis below the tip of the medial malleolus and whose attachments are hypertrophic. Its insertions to the plantar structures are broadened and some fibrous strands are added to its normal sites of attachment.

In light of these findings it is easily understood why club-foot tends to recur after treatment. The fibrous mass composing the distal end of the tendon of the tibialis posterior doubtless tends to shrink. Incomplete correction, failure of maintenance of the corrected position, and weakness of the evertors and dorsiflexors may allow this shrinking to occur with resultant relapse of the deformity. Perhaps similar fibrous masses at the medial insertion of the Achilles tendon also contribute to the relapse.

TREATMENT

Club-foot is treated at the out-patient clinic of the Beilinson Hospital by wedging plaster casts [7] as soon after birth as possible. Splints are used to main-

FIG. 6-A

FIG. 6-B

Bilateral club-foot before surgical correction (Cases 8 and 9, Table I).

FIG. 6-C

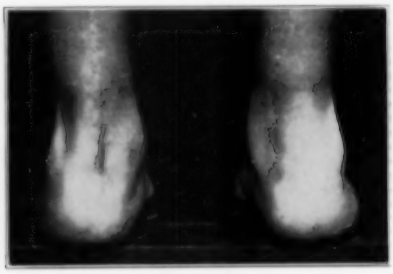

FIG. 6-D

After correction by medial release and tibialis posterior transfer, Achilles-tendon lengthening, and posterior capsulotomy.

FIG. 6-E

The transferred tendon during active dorsiflexion. Follow-up: four years.

tain the position once correction is obtained. In cases where relapse occurs, the same treatment is given. If the tendency to recur persists in spite of these measures, operative correction is considered at the age of three years or older. Four to six weeks before surgery additional treatment with a plaster cast is given if it is felt that this will improve the deformity before surgery is performed.

Surgical treatment of recurrent club-foot should correct the previously mentioned pathological condition, that is: the fibrous extensions of the tibialis posterior, the shortening of the Achilles tendon, and the weakness of the dorsiflexors of the ankle. To do this the fibrous tissues detrimental to the proper alignment of the foot should be removed. The power of the invertor muscles should be weakened and used to strengthen dorsiflexors. An operation consisting in the following steps was performed: detachment of the fibrous extensions of the tibialis posterior and of its tendon, tantamount to a medial-release operation; lengthening of the Achilles tendon and posterior capsulotomy of the ankle joint to correct equinus deformity; and transfer of the tendon of the tibialis posterior through the interosseous membrane to the anterior plane of the foot and implantation to the dorsum of the mid-portion of the foot to strengthen dorsiflexion.

Technique

The plaster cast is removed two days before surgery. The skin is prepared in the usual way, and a pneumatic tourniquet is used throughout the operation.

TABLE I

	Preoperative Findings							Postoperative Findings					
Case No.	Deformity Recurrent since Age of	Equinus Deformity *(Degrees)*	Varus Deformity of Heel	Adduction of Fore Part of Foot	Age at Operation *(Years)*	Length of Follow-up *(Years)*	Approximate Power of Transferred Muscle	Dorsiflexion of Ankle *(Degrees)*	Walking on Tip-Toe	Walking on Heel	Varus Deformity of Heel	Adduction of Fore Part of Foot	Footwear Used	Remarks
1	2 yrs.	120	Severe	Severe	4	5	4	80	Yes	Yes	No	Slight	Normal	Talo-cuneiform-metatarsal joints have not been opened.
2	3 yrs.	120	Severe	Moderate	5	5	3	75	Yes	Yes	No	No	Normal	
3	1 yr.	110	Severe	Moderate	9	5	4	75	Yes	Yes	No	No	Normal	
4	1½ yrs.	130	Severe	Severe	5	5	4	75	Yes	Yes	No	No	Normal	
5	1½ yrs.	120	Severe	Moderate	5	5	4	80	Yes	Yes	No	No	Normal	Slight valgus deformity of heel, static
6	6 mos	105	Moderate	Moderate	4	4	4	75	Yes	Yes	No	No	Normal	Overcorrected to valgus deformity; tibialis posterior inserted in cuboid
7*	3 mos.	110	Severe	Severe	5	4	3	85	Yes	No	Slight	No	Normal with lift	Has other deformities and short leg; slight varus deformity of heel persists
8	2 yrs.	135	Severe	Severe	9	4	3	95	Yes	No	Slight	No	Normal	
9	2 yrs.	135	Severe	Severe	9	4	3	80	Yes	Yes	No	No	Normal	
10	1 yr.	120	Severe	Moderate	4	4	3	85	Yes	No	No	Slight	Orthopaedic boots with lift	Has other deformities and short leg; slight adduction of fore part of the foot
11	1 yr.	110	Severe	Moderate	4½	4	4	75	Yes	Yes	No	No	Normal	
12	1 yr.	130	Severe	Severe	6	4	5	80	Yes	No	No	No	Normal	Limited mobility of talo-tibial joint
13*	3 mos.	120	Severe	Moderate	4	4	4	70	Yes	Yes	No	No	Normal	

*These feet were never really corrected by manpiulation and plaster-cast treatment.

FIG. 7-A

FIG. 7-B

Bilateral club-foot. Left foot is Case 2; right foot is not included in table since follow-up was only three years. Before surgical intervention.

FIG. 7-C

FIG. 7-D

Photographs made five years and three years, respectively, after operation.

FIG. 7-E

Photograph shows active dorsiflexion when patient stands on heels.

A curved incision is made on the medial side, from the medial malleolus to the base of the first metatarsal. The tendon of the tibialis posterior is identified near the malleolus and dissected distally until the whole tendon and its extensions are freed and detached from their insertions. The fibrous mass at the end of the tendon is trimmed down to a single strand preserving the overall length of the tendon. The capsules between the talus and navicular, navicular and first cuneiform, and first cuneiform and first metatarsal joints are incised.

A second slightly curved incision is made medial to the Achilles tendon extending from the upper margin of the calcaneus upward to the mid-portion of the calf. The tendon sheath of the tibialis posterior is opened and the tendon withdrawn. A Z-type tenotomy of the Achilles tendon is performed, the tendon of the flexor hallucis longus located, the fat of the region posterior to the ankle joint excised, and the ankle joint opened from behind. Division of the joint capsule is done, radical enough to gain full correction of the equinus deformity. To gain full correction, it is often necessary to enter the joint space with a small tenotome and to divide partially the calcaneofibular and deltoid ligaments, carefully avoiding the medial neurovascular bundle. The interosseous membrane is exposed by blunt dissection at its attachment to the tibia from the proximal end of the wound distally to the medial malleolus. The membrane is then opened

FIG. 8-A

FIG. 8-B

Bilateral recurrent club-foot (Cases 4 and 5, Table I). Before surgical correction.

FIG. 8-C

FIG. 8-D

Photographs made after operation. Follow-up: five years.

by a small incision without peeling the periosteum of the tibia. A blunt instrument, preferably a broad probe with an eye, is pushed through the opening and directed to the anterior aspect of the lower part of the leg.

A third skin incision is made in the distal part of the anterior surface of the lower part of the leg. The deep fascia is incised, the end of the probe palpated and its point redirected to emerge between the bellies of the extensor hallucis and extensor digitorum longus. The free end of the tendon of the posterior tibialis is then pulled through the eye of the probe which in turn is drawn out together with the tendon into the anterior incision. The Achilles tendon is sutured after the necessary lengthening, and the first and second skin incisions are closed.

A fourth incision is made over the third cuneiform bone on the dorsum of the foot. The tendons of the extensor digitorum longus are retracted to the lateral side and the bone exposed. A canal is drilled in a dorsoplantar direction through the bone to receive the tendon. The tendon of the tibialis posterior is brought down through the common extensor-tendon sheath with the help of the same probe. Its end is sutured into the hole in the third cuneiform bone with the aid of a Bunnell pull-out wire suture to the skin of the sole of the foot after passing it through the prepared canal.

The third and fourth incisions are sutured. The wounds are dressed and a padded plaster-of-Paris cast applied, holding the foot in 90 degrees of dorsiflexion and slight valgus. The cast is cut along its length to allow for postoperative swelling. After from seven to ten days the plaster is changed for a below-the-knee walking plaster boot, and weight-bearing is allowed. After six weeks the plaster is removed; a night splint is used for an additional three months and exercises to strengthen dorsiflexion are performed during the same period.

MATERIAL

Until now operations using this technique have been performed on patients with fifty-six cases of recurrent club-feet. Five feet were operated upon in 1953; eight in 1954; eight in 1955; twelve in 1956; fourteen in 1957; and nine in 1958. The findings were similar in all of these operations, confirming the presence of fibrosis and the increase of fibrous connections of the distal end of the tendon of the tibialis posterior.

The first thirteen patients have been followed for from four to five years. Only the results of these are reported here (Table I) since it was felt that further changes, as the result of growth or muscle imbalance, might occur in the feet of small children. Most of the children recorded in Table I have now reached the age at which the results may be considered final.

The ages at the time of operation of the children reported here were: five, four years old; four, five years old; one, six years old; and three, nine years old. The average age at operation was 5.6 years. These feet had all been treated conservatively for long periods of time before operation. Two of them had never been corrected satisfactorily, the others had recurred one to three years after good primary correction by manipulation and plaster casts.

Rating of the results of the operation was based on the correction of each of the components of the deformity and the function of the foot. The results were: *excellent*, seven feet; *satisfactory*, five feet; and *unsatisfactory*, one foot. A result was considered *excellent* in those feet where no deformity whatsoever remained, where normal alignment of the feet was seen in standing and walking, and where the child was able to walk on his heels with the feet in dorsiflexion. A result was considered *satisfactory* in a foot which showed some minor residual deformity such as slight varus deformity of the heel or adduction of the fore part of the foot, or a foot which presented full correction of the deformity but which did not permit the child to walk on his heel with the foot dorsiflexed.

The one result considered *unsatisfactory* in this series was due to over-correction of a foot in which the tendon of the tibialis posterior was inserted into the cuboid instead of the third cuneiform.

All but two of the patients wore ordinary shoes without difficulty. These two patients had leg-length discrepancy because of other congenital deformities and were provided with the necessary orthopaedic footwear (Figs. 6-A through 8-D).

DISCUSSION

The theoretical assumption that the tibialis posterior should be important in the production of club-foot seems to have been confirmed by the findings in each of the fifty-six operations performed on patients with recurrent club-foot. Two of the patients had no previous treatment and therefore the deformity should not be classified as recurrent. Even these showed the same fibrous hypertrophy of the insertion of the tendon of the tibialis posterior with extensions to many structures of the foot, distributed in such a fashion that the foot was held in the position of deformity. This finding, therefore, does not seem to be the result of previous treatment. Of course, the other pathological findings [11] which have been described in club-foot contribute to the deformity, but the importance of the changes in the tendon of the tibialis posterior, as a major deforming factor, has not been stressed before.

The transfer of the tibialis posterior to the dorsum of the foot, according to known techniques [10,16], enables the surgeon to increase dorsiflexion power and to weaken inversion power of the foot. It is, of course, very difficult to assess the real power of muscles in patients with club-foot, since many muscles seem weak and limitation of joint mobility may give the impression of increased power in deformed muscles. In general it is agreed that peroneal power is weakened, probably by overstretching of the stronger invertors. The atrophy of the calf observed so frequently in club-foot indicates weakness of the triceps group, but tip-

toe walking after correction was possible in many of our patients. The assessment of the power in the transferred tibialis posterior (Table I) is not entirely accurate. Its tendon lies in the immediate neighborhood of the tendons of the extensor digitorum longus and acts in dorsiflexion together with the other three extensors.

It is very important to release all the structures holding the foot in the equinus position. This is done first by lengthening the Achilles tendon and then by a thorough posterior capsulotomy. The latter seems more important than tendon-lengthening, for correction of the equinus deformity during operation was observed to occur quite dramatically when the capsular structures were cut radically. Only good correction of the equinus deformity enables the surgeon to insert the tendon of the tibialis posterior into the third cuneiform for it is always quite short.

The insertion of the tendon should never be made too far laterally. In Case 6, this produced a valgoplanus deformity. Muscle balance in the child's foot is always precarious. In the normal foot, a powerless tibialis posterior produces severe valgoplanus. Only the tendency of the skeletal structures to remain in a varus position, the small inversion power of the toe flexors, and the weak peronaei can account for the results achieved in these patients with club-foot. Transfer of the tibialis posterior too far laterally produces additional eversion power and overcorrection leading to valgoplanus.

The widely used transfer of the tibialis anterior to the cuboid is a much simpler procedure[5,8,9] but it does not increase dorsiflexion power. Singer and Fripp found that relapse occurred fifty-two times in seventy-six feet on which this procedure had been performed.

Operative correction of recurrent club-foot should be undertaken before bone deformity is irreversible, between the ages of four and six years. In the cases not included in Table I many operations were done at the age of three, if recurrences had occurred early and were severe enough to warrant the hastening of surgical intervention. After the age of nine the feet are too rigid to allow correction by soft-tissue surgery alone. Partial resection of tarsal bones or some kind of stabilization is necessary for satisfactory results.

The good results of the operative procedure in patients reported in this paper have also been seen in the patients who have not as yet been followed for four years or more. Up to now only two recurrences have occurred, one due to faulty technique and the other to many associated deformities including fusion of several tarsal bones. The operation described here has proved to be superior to other techniques at least in the experience of the author. Parents of children with bilateral club-foot almost always return after correction of the more deformed foot to ask for correction of the other foot. The immediate result achieved by the operation has been observed to improve during the first postoperative year, probably due to the gain in power of the transferred muscles. No further changes were observed after this time.

Four of the thirteen patients mentioned in Table I were unable to walk on their heels. This seems to be the result of insufficient release of the equinus contracture, since all of the patients with at least 80 degrees of dorsiflexion at the ankle were able to walk on the heels. Those who had less than 80 degrees of dorsiflexion could not do this or recurvatum of the knee developed to enable heel-walking. The power of the triceps muscle did not seem to be the deciding factor with respect to the ability to walk on tip-toe.

Good results in twelve of the thirteen feet operated on for this deformity are encouraging enough to recommend further trial of this procedure. The small number of patients with adequate follow-up makes this report a preliminary one. The number of patients who have been operated on since those reported here who show at the present time the same over-all results is encouraging. The results in these feet will be reported at a later date.

SUMMARY

The insertion of the tendon of the tibialis posterior has been dissected in fifty-six feet with recurrent club-foot. This insertion was abnormal in all instances. The tendon was thickened and at the medial malleolus changed into a thick fibrous mass, inserting with extensions to fascia, ligaments, and bones at the medial, dorsal, and plantar aspects of the foot.

As the tibialis posterior is the only muscle able to produce club-foot by its contraction or shortening alone, deformity of this muscle is seen as one of the main reasons for the development of club-foot. Considering this, the tibialis posterior was transferred, after excision of the abnormal insertion, to the anterior plane of the foot and sutured to the third cuneiform. Achilles-tendon lengthening and posterior capsulotomy were performed at the same time to overcome equinus deformity.

Thirteen of the patients were followed for at least four years. Good results were obtained in twelve patients; seven of the results were classified as *excellent* with full correction of deformity and full function. In five, some minor deformity remained or walking on tip-toe was not possible. Overcorrection resulted in one patient and the result was regarded as *unsatisfactory*.

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Considerations on the Surgical Treatment of Slipped Epiphysis with Special Reference to Nail Fixation*

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As yet the only thing we can do in the treatment of slipped epiphysis of the femoral head is to try to detect the condition as early as possible and prevent further slipping. If slipping is advanced, attempts must be made to improve the position of the epiphysis. If slipping is slight to moderate, the epiphysis may be fixed without preliminary correction of its position since such a degree of slipping does not seriously impair function and any secondary arthritic changes are usually slight.

Howorth, in 1941 and 1949, reviewed a large series of patients with slipped upper femoral epiphyses treated by the method he had been using since 1930. He secures fixation by inserting bone pegs through drill holes across the epiphyseal plate. (A similar method has since been described by Heyman and Herndon.) In Howorth's method the results he achieved must be regarded as very good; there was no aseptic necrosis nor did any serious complication occur in the 200 hips operated on. The only disadvantage of his method is the relatively long interval before weight-bearing is allowed. This period varies with the age of the child and the state of the epiphyseal plate. Howorth permitted weight-bearing about ten weeks postoperatively. It was mainly because of the length of this period that Waldenström, in Sweden, recommended nailing according to the method described by Wilson in 1938; fixation of the epiphysis with a three-flanged nail, a method which has since been widely used in our country and with which this paper is concerned.

All the patients in the series presented in this paper were operated upon at three hospitals; Lund, in 1942; Gothenburg, in 1948; and Hälsingborg, from 1946 to October 1956.

General anaesthesia was given to the patient and two x-ray tubes were placed in position at the operating table. Thus, roentgenographic control in anteroposterior as well as the lateral projection could be obtained during the course of the operation, permitting accurate insertion of the nail. Postoperatively, full weight-bearing was allowed after an average of eight days.

Three types of nails were used (Fig. 1); a Sven Johansson nail of stainless steel, a Vitallium nail of essentially the same type, and a stainless-steel nail called the Nyström nail. The Sven Johansson nail was used in as many as 110 patients, the Vitallium nail in only four, and the Nyström nail in seventy-one (Table I). The degree of slipping is given in Table II.

The value of an operative method must be determined by the frequency and severity of early and late complications. In the evaluation of the relative value of the surgical procedures under discussion, the following complications may be considered. In early complications there may be: driving away of the

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epiphysis by the nail; bending of the guide wire; and perforation of the cortex of the head by the nail. In late complications, the nail may lose its grip in the epiphysis because of true gliding or "shortening" of the nail (the nail has become too short because of growth of the femoral neck); the femur may fracture at the level of the nail; and there may be necrosis of the femoral head. The most important criterion is the frequency of necrosis. If this complication occurs, it is apparent within one year. In the present series, the average interval between the operation and re-examination was two years and two months and in no instance was the interval less than one year.

TABLE I

MATERIAL GROUPED ACCORDING TO TYPE OF NAIL (185 Hips)

Type of Nail	Operation Performed at	No. of Patients	Female	Male	Age (Years) Youngest	Oldest	Average	No. of Hips	Side Nailed Right	Left	Bilateral
Sven Johansson (110 hips)	Lund	44	17	27	10.4	17	13.3	51	11	26	7
	Hälsingborg	34	10	24	8	23	13.8	39	11	18	5
	Gothenburg	18	4	14	11	16	13.7	20	6	10	2
Vitallium (4 hips)	Lund	4	1	3	13.1	14.3	13.3	4	2	2	
Nyström (71 hips)	Lund	3	1	2	9.3	15.8	12	4	1	1	1
	Hälsingborg	4		4	15	17	16	4		4	
	Gothenburg	46	19	27	10	17	13.3	63	10	19	17

TABLE II

DEGREE OF SLIPPING OF EPIPHYSIS ON SIDE NAILED

Operation Performed at	Slipping*	Type of Nail: Sven Johansson	Vitallium	Nyström
Lund	Slight	38	4	2
	Moderate	13		2
	Severe			
Hälsingborg	Slight	33		
	Moderate	6		4
	Severe			
Gothenburg	Slight	6		23
	Moderate	14		39
	Severe			1

*Slight, 106 hips; moderate, 78 hips; severe, 1 hip

Sometimes a serious complication such as driving away of the epiphysis with diastasis between the latter and the femoral neck occurs during the operation (Fig. 2-A); Wilson [17] was the first to describe this complication. In our series of hips operated upon it occurred in seven patients; in six, after the use of a Sven Johansson nail, and in one, after the use of a Vitallium nail. Of these, in six patients the tip of the nail pierced the epiphysis, which it had gripped. In three of the six patients, the diastasis was eliminated by hammering on the outside of the femoral shaft. No particular measures were taken in the remaining three and the diastasis disappeared soon after weight-bearing was started (eight days after operation in all six). In the seventh patient, the one in whom a Vitallium nail was used, the epiphysis, although not pierced by the nail, was lifted. The

nail was immediately withdrawn and a Sven Johansson nail substituted; the same result followed. This is not so astonishing because the epiphysis must have been quite loose. We then used three Nyström nails without any consequent diastasis (Fig. 2-B); the functional end result was good. Aseptic necrosis did not follow this inadvertent displacement of the epiphysis in any of the seven patients. Examination of the roentgenograms showed that in some instances the nails had been driven eccentrically. This might have contributed to the lifting of the epiphysis, although the position of the nail was also eccentric in some patients in whom the epiphysis had not been lifted. It is important, however, to place the nail as centrally as possible in the epiphysis, because the lifting effect is less when the nail is directed against the middle of the epiphysis than when it is directed against one of the edges. In addition, if the nail is in the center it might get a deeper grip in the epiphysis and thereby decrease the risk of the nail's being too short when the femoral neck grows.

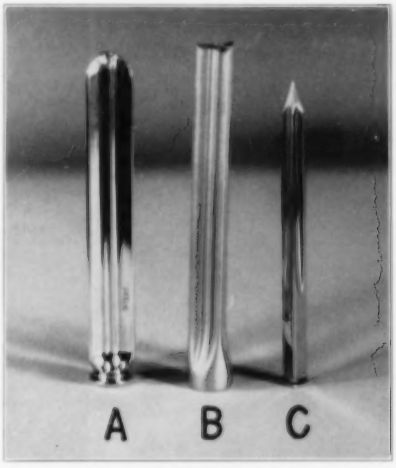

FIG. 1

Photograph of nails used: *A*, Sven Johansson; *B*, Vitallium; and *C*, Nyström.

It was noteworthy that the nails used in all the seven patients in whom the epiphysis had lifted were thick. This seems to point to the fact that a blunt nail is more liable to produce a complication of this type than a pointed nail. Other clinics reported driving away of the epiphysis with the Sven Johansson nails, and because of this reaffirmation, the Gothenburg clinic decided to use Nyström nails.

As we know, the Sven Johansson or Vitallium nails are threaded over a previously inserted guide wire. In three instances, the Sven Johansson nail did not follow the guide wire with the result that the wire was bent at the tip of the nail. This complication made it difficult to withdraw the guide wire after the nail had been driven in. When this occurs, the nail must be withdrawn and a new one inserted. During one procedure when attempting to extract the guide wire it broke near the tip. It was impossible to withdraw the fragment of the tip and it was therefore left *in situ*. Fortunately the fragment did not affect the joint or produce any subsequent difficulty.

This relatively rare complication can be avoided by taking the precaution of making roentgenograms during the operative procedure. In this way, one can see if the nail has followed the guide wire while the head of the nail is still projecting from one to two centimeters outside the femoral shaft. At this stage of the operation it is not difficult to withdraw the nail.

In fifteen patients, the tip of the nail pierced the cortex of the femoral head; the nail was either too long or had been driven in too far. In five, the tip of the nail lay just barely through the cortex and the roentgenograms showed that it was within the articular cartilage which precluded further measures being taken. In the remaining ten, the nail was withdrawn a few millimeters. Penetration of the cortex, especially in the superior half of the femoral head, has been known to cause aseptic necrosis. The end results were good, however, in all fifteen patients.

As previously mentioned, the nail should be driven as far as possible into the epiphysis because of the later growth of the femoral neck, but this does not, of course, imply that the nail should pierce the cortex of the head. Although the nail did not slide out in any of these fifteen patients, slight withdrawal of a nail might

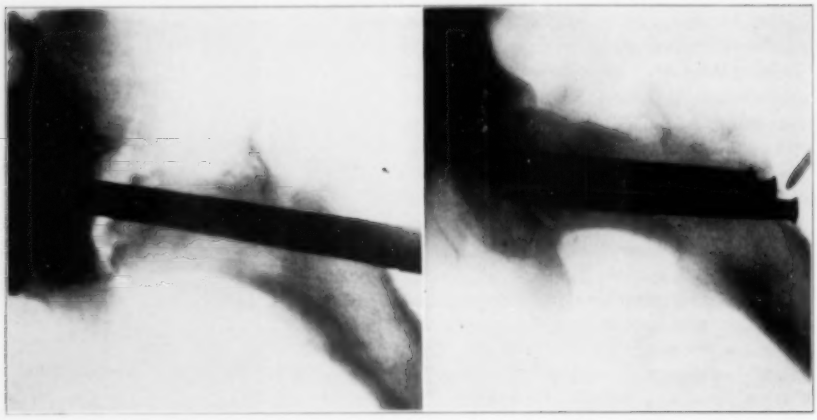

FIG. 2-A FIG. 2-B

Fig. 2-A: Roentgenogram of hip in which the Vitallium nail is driving away the epiphysis.
Fig. 2-B: Diastasis has disappeared after nailing with three Nyström nails.

jeopardize its grip in the bone. With the aid of the guide wire, the surgeon should therefore determine, as accurately as possible, the most suitable length of the nail before he inserts it.

The tip of the nail sometimes loses its grip in the epiphysis; this may be due either to true gliding of the nail (Fig. 3) or to growth in length of the femoral neck with migration of the epiphysis from the tip of the nail, the latter being anchored by its head in the femoral cortex (Fig. 4). Renailing proved necessary in seventeen patients although in sixteen no further slipping occurred. In one, however, the femoral head slipped so markedly that we had to do a wedge osteotomy of the neck. A later complication in this patient was the development of necrosis of the head. The danger of shortening of the nail due to true gliding or to growth of the femoral neck, makes it necessary to insert the nail as far as possible into the epiphysis, especially in young patients with a long period of growth left. To minimize the tendency of the nail to slip out, it should be driven in so that the head lies at the level of or within the lateral femoral cortex in order to get good anchorage there (Figs. 5-A and 5-B). In addition, postoperative roentgenograms made at regular intervals, should be continued until the epiphyseal line has definitely closed.

In four patients the femur fractured at the level of the head of the nail (Fig. 6). Three Sven Johansson nails and one Nyström nail was used in these patients. In all instances the fracture was due to an accident which occurred within one year after the operation (one, two, seven, and twelve months, respectively). The fractures were treated in the usual way and healed in good position without any complications of the hip joint. It is obvious that the femoral shaft will be somewhat weaker at the level of the head of the nail, especially if the nail is thick. One might wonder whether it would not have been advisable to remove the nail in these four patients. At any rate this was not possible because the epiphysis had not closed.

An earlier series of fifty-eight nailed hips [15] included one patient with partial necrosis of the femoral head which healed and remained symptom-free. In the present series of 185 cases necrosis of the femoral head occurred in two patients; in one it was only partial and later healed, but in the other the entire head was involved and function of the hip was severely impaired. An analysis of this patient's record sheet, including the report of the operation and postoperative management, failed to provide any clue as to the cause of the necrosis. (It thus appears that this complication must occasionally be expected.) The necrosis oc-

FIG. 3 FIG. 4

Fig. 3: True gliding of the nail (the nail has lost its grip in the epiphysis).
Fig. 4: Relative shortening of the nail due to growth of the femoral neck (the nail has lost its grip in the epiphysis).

curred after nailing with a Johansson nail, but one cannot be sure whether the necrosis had anything to do with the type of nail.

Although several complications may occur in association with nailing they seldom lead to any permanent injury to the hip. Thus in the present series, there was only one patient with total necrosis of the femoral head who had poor end results. In all of the others function was just as good as before the operation. For the sake of completeness I might add that necrosis of the articular cartilage occurred in two patients, but this frequency is, if anything, lower than in conservatively treated cases and therefore can hardly be regarded as a drawback of the method.

It may thus be claimed that nailing is a satisfactory method for the treatment of slight and moderate slipping of the epiphysis. As to the frequency of complications in regard to the two types of nails—the thick three-flanged nail and the thinner Nyström nail—it was lower for the Nyström nail, especially in driving away of the epiphysis and fracture of the femoral shaft. The only disadvantage of the method is that the insertion of the nail is somewhat more difficult because one must drive in the nail alongside the guide wire, but this is, after all, not so difficult, and it can hardly be denied that the Nyström nail has certain advantages over the Sven Johansson nail. The Nyström nail would probably be still better if it were made of Vitallium and if it were not quite so pointed.

Although it is somewhat beyond the scope of the present paper, a few words on slipping of the epiphysis on the unaffected side might not be out of place. In the present material, follow-up revealed such slipping in twenty-four patients. In twenty-two the epiphysis could be nailed before it had slipped to any appreciable extent. In two patients, however, slipping was pronounced and one required wedge osteotomy of the femoral neck. The tendency of the unaffected side toward slipping was the reason why some authors suggested that it might be wise to nail the healthy side as a prophylactic measure. To our knowledge, however, less

TABLE III

PATIENTS WITH WEDGE OSTEOTOMY OF THE FEMORAL NECK (46 Hips)

Operation Performed at	No. of Patients	Female	Male	Age (Years) Youngest	Oldest	Average	No. of Hips	Side Operated Upon: Right	Left	Bilateral
Lund	19	5	14	11	16.5	13.5	20	6	12	1
Hälsingborg	5	2	3	11	17	14.2	5		5	
Gothenburg	21	4	17	11	18	14.3	21	5	16	

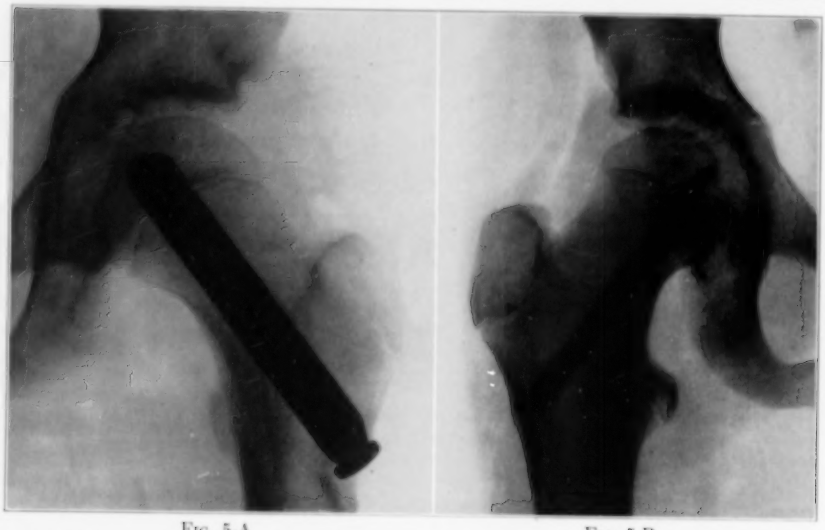

FIG. 5-A FIG. 5-B

Roentgenograms show hips with perfect nailing: the head of the Sven Johansson nail (Fig. 5-A) and the Nyström nail (Fig. 5-B) are well anchored in the cortex of the femur.

than half of the cases are bilateral and according to Jerre, the incidence is 42.6 per cent. This low incidence is hardly a substantial reason for such a prophylactic measure. For the time being it might be just as well to re-examine the patient carefully every second or third month so that any slipping on the unaffected side may be detected in good time.

If we compare the results obtained by the nailing method and those achieved by Howorth with the bone-peg method, it is obvious that Howorth's method is attended by fewer complications; it is at any rate superior to that in which a blunt nail is used and just as good as that employing a Nyström nail. The disadvantage of Howorth's method is the relatively long time the patient must walk on crutches—about two months—a disadvantage which weighs heavily against the advantages of nailing, which allows the patients to be on their feet again within eight to ten days. At present, it is difficult to say whether one method is really better than the other. If Howorth's method would permit earlier use of the hip, it would undoubtedly be preferable and Howorth has possibly been too conservative in delaying weight-bearing so long. Now let us consider those patients with pronounced slipping. As we previously mentioned, function of the hip in these patients is poor and osteo-arthritis is liable to develop. This is why attempts have been made to correct the position of the slipped epiphysis surgically. The methods hitherto used have been subtrochanteric osteotomy, replacement and fixation of the epiphysis, and, finally, wedge osteotomy of the femoral neck.

I have not been able to find any reviews of a large series of patients treated by subtrochanteric osteotomy, but cases of necrosis of the femoral head are on record. In view of the vascular anatomy of this region, this complication ought to

TABLE IV

FREQUENCY OF NECROSIS OF THE FEMORAL HEAD FOLLOWING WEDGE OSTEOTOMY (27 Per cent)

Operation Performed at	No. of Cases	Incidence of Necrosis
Lund	20	3
Hälsingborg	5	2
Gothenburg	21	4
Sub total	46	9
Stockholm	38	14
Total	84	23

be rare. There is no doubt that such osteotomy produces a marked improvement in the functional result and that the operation is justified.

Opinions differ as to open reduction of the epiphysis. Klein and his associates reported relatively good results. Howorth [7], on the other hand, found that a large proportion of patients had poor results.

Wedge osteotomy of the femoral neck has been widely used and some authors, for example, Martin, Wagner, and Compere, reported good results. Others, however, including Badgley and Howorth [7] have had the opposite experience; Badgley, for instance, reported that 32 per cent of his patients had poor results. The operative procedure has varied from one series to another, but it seems that the operative procedures as performed by Badgley and Martin are the most frequently used. The results depend, to no small extent, on the technical performance. Even with a good technique, however, necrosis of the epiphysis must be expected in some patients owing to the position of the blood vessels in the region of the femoral neck and head. Although other complications, such as wound infection or fracture of the nail material, may occur, it is necrosis of the femoral head that is responsible for the poor results.

FIG. 6

Fracture of the femoral shaft at the level of the nail head.

Wedge osteotomy has also been used in Sweden following the technique described by Badgley. We fixed the epiphysis either by screw or nail and then immobilized the hip in plaster for a postoperative period of four to six weeks. Since a wider knowledge of the results which may be expected with wedge osteotomy might be of value, those obtained in Sweden are recorded here with special reference to the frequency of necrosis of the femoral head. The information was collected from the clinics previously mentioned and a survey of forty-six cases is presented in Table III. There were two hips in which moderate slipping of the epiphysis occurred and forty-four in which the slipping was severe. Partial or total necrosis of the femoral head occurred in nine patients and in all the result was a poor joint (Table IV). In order to find a wider basis for evaluating the frequency of this complication, Table IV includes a series, published in 1955, from the Stockholm clinic where the same operative procedure was used. It is clear

from this series that partial or total necrosis of the femoral head which caused poor functional end results occurred in fourteen of the thirty-eight patients operated upon. Thus, of a total of eighty-four wedge osteotomies of the femoral neck, necrotic changes were the result of as many as twenty-three (27 per cent). This result cannot be regarded as satisfactory. In view of the obvious risks of this method, one must question whether it is really justified.

If all of the patients had been left untreated, the function of the joints would certainly have been poor, but it would have been sufficient for normal use for several years. Osteo-arthritic changes appearing, say, at the age of fifty, could have been treated surgically at that time. Furthermore, we do not know the subsequent fate of the patients who had successful results. It is true that we do restore function of the joint, but it is an intra-articular operation, and this alone may imply an increased risk of secondary osteo-arthritic change. Only the future can answer this question. Even though it may be possible to improve the method technically, I think it wise to be cautious in the use of wedge osteotomy of the femoral neck. I should very much like to see a review of a series of patients treated by subtrochanteric osteotomy because there is reason to ask whether a revival of this operative method might not be justified.

Although slipped epiphysis is not a common condition, it is of significant importance for the simple reason that it affects young people, and any treatment liable to jeopardize the future function of the joint should be avoided. Although fixation of the epiphysis *in situ* by a nail is fully acceptable, the use of wedge osteotomy of the femoral neck must be questioned.

SUMMARY

Conservative treatment of slipped epiphysis has now been superseded by surgical procedures. If the slipping is slight or moderate, bone-pegging or fixation *in situ* with a nail is indicated. In our series of 185 nailed hips, the complications which occurred in the patients operated upon were: driving away of the epiphysis, bending of the guide wire, perforation of the cortex of the femoral head, gliding of the nail, femoral fracture, and necrosis of the femoral head. Only in one patient had complicating necrosis of the femoral head any permanent effect on the hip. The frequency of complications was lower following the use of blunt three-flanged nails. Wedge osteotomy of the femoral neck performed on patients in the series of eighty-four hips was followed by necrosis in 27 per cent and it is questionable whether this method is justified.

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The Origin of the Artery of the Ligamentum Teres Femoris

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The role of the artery of the ligamentum teres femoris, the foveolar artery, in the blood supply of the femoral head has been the subject of much controversy. The investigations of Wolcott and Tucker gave an insight into the importance of this vessel. Trueta and Harrison clarified the role of the vessel in the adult, and the more recent work of Trueta seems to have given the proper perspective to the function of the artery in children. According to Trueta the foveolar artery does not penetrate the femoral head until age eight or nine. It shortly thereafter forms an anastomosis with the lateral epiphyseal vessels, and at puberty a union with the metaphyseal arteries takes place. Thus, it may become an important source of blood to the femoral head, especially in instances of damage to the other vessels.

With the established importance of the foveolar artery, it seemed advisable to reinvestigate the origin of this vessel. It is well known that the foveolar branch is derived from the acetabular artery whose origin, however, is not clear. Cunningham, Gray, and Testut indicate that both the obturator and medial femoral circumflex arteries give rise to acetabular branches, and from each branch a foveolar artery passes along the ligamentum teres to the femoral head. Morris indicates that the foveolar artery is an indirect branch of the obturator artery only, although a branch of the medial femoral circumflex to the acetabular fossa is described without mention of any contribution to the femoral head. Grant states that both the medial femoral circumflex and obturator arteries send branches under the transverse ligament to the acetabular fossa and that one or the other of these vessels passes along the ligamentum teres to the femoral head. Woodburne describes the foveolar artery as a branch of the obturator, but indicates that the medial femoral circumflex artery has an acetabular branch which anastomoses with the one from the obturator. Howe, Lacey, and Schwartz, in a study of forty adult hips, reported

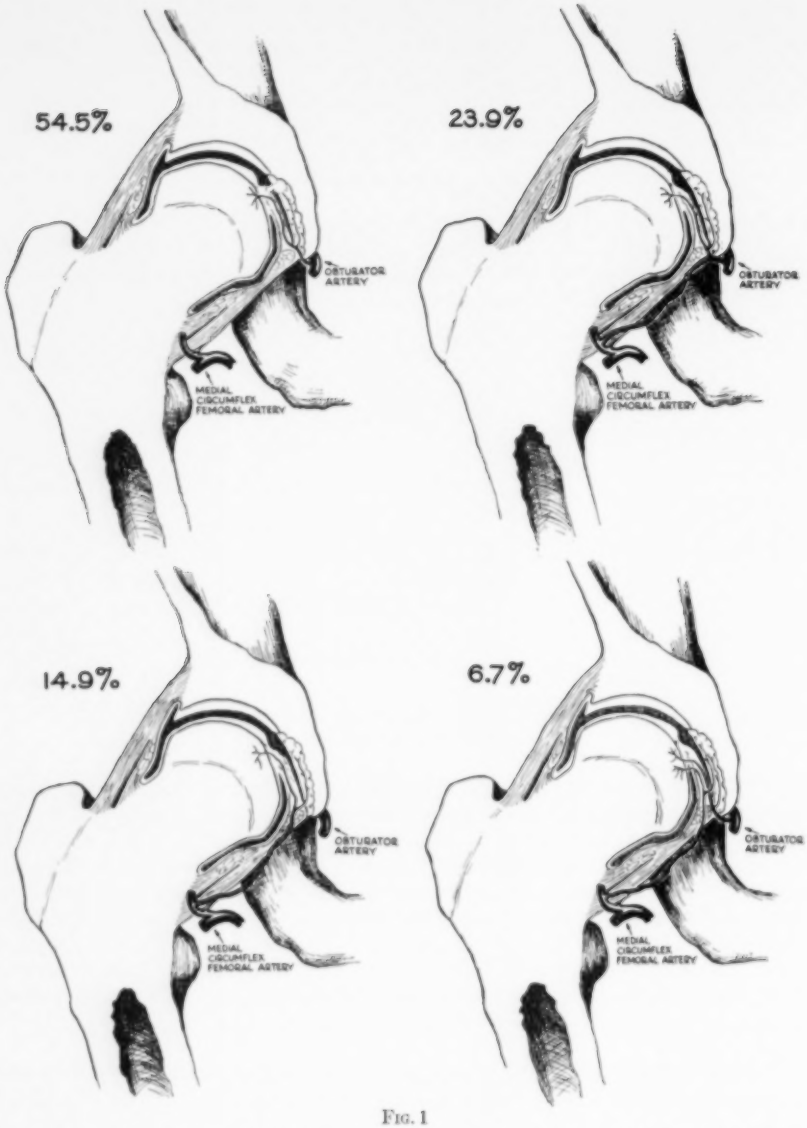

FIG. 1

Schematic representation of the frequency of patterns of origin of the foveolar artery.

that it was only the obturator artery which contributed to the femoral head by way of the ligament.

MATERIALS AND METHODS

The specimens used in this study were almost exclusively from full-term stillborn infants. There was an approximately equal division between white and Negro and between male and female bodies. One hundred and thirty-four hips were injected with latex by way of the common iliac artery. Sufficient pressure was used to cause satisfactory filling of even the smaller vessels. Gross dissection of the specimens was used to determine the origin of the vessels passing along the ligamentum teres to the femoral head.

OBSERVATIONS

In the 134 specimens, the acetabular artery, and consequently the foveolar branch, arose solely from the obturator artery in seventy-three (54.5 per cent). Immediately after leaving the obturator canal, the obturator artery branched into anterior and posterior divisions. The posterior division passed deep to the obturator externus muscle, and at the acetabular notch gave off the acetabular branch which passed under the transverse acetabular ligament. In the fat of the acetabulum, a small branch passed to the ligamentum teres. It coursed in the superomedial aspect of the ligament frequently dividing into two or three vessels of macroscopic size. These principal vessels commonly traversed the entire length of the ligament and sprayed out onto the fovea.

The medial femoral circumflex artery provided the only branch to the fovea in twenty specimens (14.9 per cent). As the deep division of this artery coursed along the obturator externus muscle, a typical acetabular branch passed under the transverse ligament and supplied the fovea with one or two branches by way of the ligamentum teres.

In only nine instances (6.7 per cent), was there an acetabular branch from both the medial femoral circumflex and obturator arteries, each of which provided a direct foveolar artery to the femoral head. In the remaining thirty-two specimens (23.9 per cent), there was an anastomotic connection of rather large size between the obturator and medial femoral circumflex arteries near the adductor brevis. From this union, a single acetabular artery originated, from which the foveolar artery was derived.

No significant difference in the origin of the foveolar artery was noted between male and female or between white and Negro specimens.

SUMMARY

One hundred and thirty-four stillborn specimens were arterially injected with latex and dissected to determine the origin of the foveolar artery. The obturator artery supplied this branch in 54.5 per cent and the medial femoral circumflex artery in 14.9 per cent. Separate foveolar branches arose from both these vessels in 6.7 per cent, while in the remaining 23.9 per cent an anastomotic connection between the obturator and medial femoral circumflex gave origin to the foveolar artery.

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Hemangioma of the Synovial Membrane*†

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The purpose of this paper is: (1) to present data from eleven proved cases of hemangioma of the synovial membrane seen at the Mayo Clinic from 1907 through 1956; (2) to compare the findings in these cases with those in forty-seven cases previously reported in the literature; and (3) to suggest that synovial hemangiomata represent a distinct clinical entity characterized in most instances by a rather constant group of physical signs which, coupled with the typical history, make preoperative diagnosis relatively definite once the possibility of the entity is considered.

Prior to 1939, cases of synovial hemangioma were reported sporadically. At that time, Bennett and Cobey first recognized the constancy of the historical facts and the physical findings in these patients and established the relationship between the typical clinical picture, the operative findings, and the pathological entity. In a careful search of the literature, these writers found reports of twenty-four cases to which they added five of their own. They pointed out the salient features of the history which, we recognize today, should lead one to suspect the presence of the disease. Almost all their cases occurred in young persons who gave a long history of recurrent episodes of pain in the knee which were not preceded by trauma and that gradually resolved in a short time, usually without treatment. They pointed out that oftentimes there was an exquisitely tender mass that felt doughy. The mass was usually distensible and compressible and could often be made to decrease in size by elevation of the part. They described and reported the results of irradiation and surgical treatment of synovial hemangiomata. They also correlated the pathological characteristics of the tumor with the results of different types of treatment. Subsequent to 1939, eighteen case reports were added to the literature[2-11,13,14,16,17] with essentially no change in either the expected clinical findings or the results of therapy.

CLINICAL FEATURES

Because synovial hemangioma is rare and the relatively typical clinical picture is not commonly recognized, it is seldom diagnosed preoperatively. In only four of the eleven patients in our series was the diagnosis made before operation. In three of these patients it was made by clinicians who had had personal experience with similar cases; in the other patient, there were multiple cutaneous hemangiomata which gave a clue to making the diagnosis in the adjacent joint.

History

Synovial hemangioma typically occurs in adolescents or young adults, but the patient usually gives a history of disturbance in the joint dating back to

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‡ The Mayo Foundation, Rochester, Minnesota, is part of the Graduate School of the University of Minnesota.

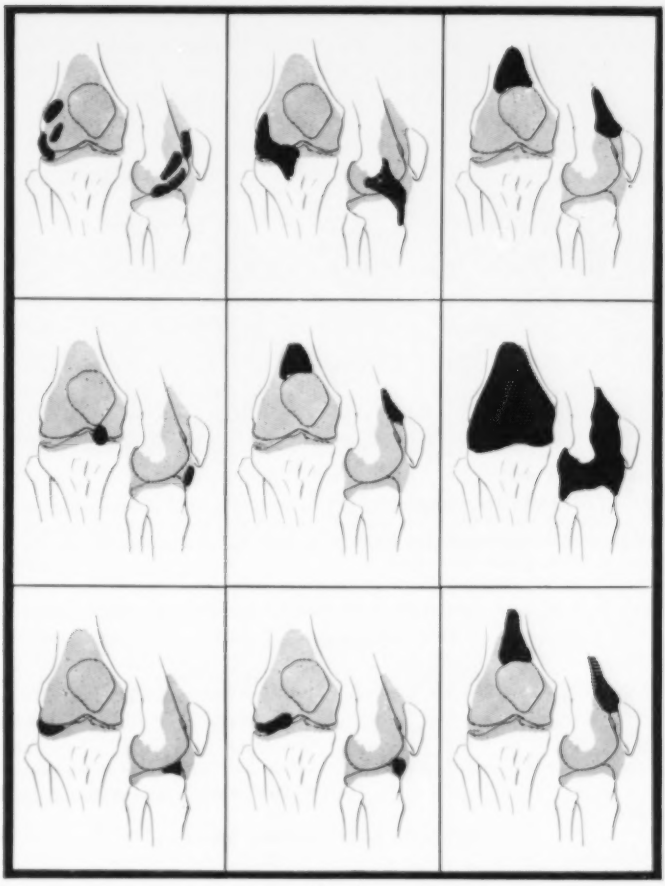

FIG. 1

Schematic representation of gross configuration and location of tumor in nine patients with involvement of the knee joint.

early childhood. Pertinent data regarding clinical features are given in Table I.

Two patients with hemangioma involving the knee joint gave a history of locking. In both, a discrete pedunculated tumor actually caused a mechanical block to extension. In another patient who had a history of locking, the locking was due to the presence of multiple osteocartilaginous loose bodies. This case history was reported by Sabanas and Ghormley, in 1955, because of the association of hemangioma with synovial osteochondromatosis.

Physical Signs

Certain features seem common to all of the cases of hemangioma regardless of the location of the tumor (Table II). Tenderness occurred in all patients in our series. It was diffuse in a few, but was well localized in a definite region, usually directly over the palpable mass, in the majority. It was exquisite in some patients.

Pain on motion occurred in every patient regardless of the joint involved. This sign was recorded in most of the cases reported in the literature and hence is a common, even though somewhat non-specific, finding.

There was marked visible atrophy of the quadriceps in seven of the nine

patients in whom the knee was affected. In two of the seven patients the instability occasioned by this atrophy was the major complaint. No explanation has been offered for this extreme atrophy which seems out of all proportion to the amount expected from disuse alone; many investigators have commented upon its existence, and it probably is one of the most important clinical signs of synovial hemangioma of the knee.

A mass was felt in six of the nine patients with involvement of the knee

TABLE I

CLINICAL FEATURES OF SYNOVIAL HEMANGIOMA

Feature	Present Group	Reported Cases
Ratio of males to females	6:5	5:6
Mean age when first seen (*years*)	20.3	18
Mean duration of symptoms (*years*)	15	6
Mean age at onset (*years*)	5.3	11
History of trauma (*per cent*)	9	45
Pain and swelling (*per cent*)	100	100
Intermittent symptoms (*per cent*)	91	81
Symptoms of internal derangement (*per cent*)	33	
Family history of hemangioma (*per cent*)	9	

TABLE II

PHYSICAL SIGNS OF SYNOVIAL HEMANGIOMA

Sign	Present group (*Per cent*)	Reported cases (*Per cent*)
Tenderness	100	54
Pain on motion	100	63
Limp	90	52
Limitation of motion	82	45
Muscle atrophy	78	50
Mass	73	69
Hemangiomata elsewhere	27	
Leg-length discrepancy	22	
Crepitus	18	20

joint (Fig. 1) and in two patients with involvement of the elbow and ankle, respectively. It was diffuse and poorly defined in most instances. It felt doughy in three patients, including the one in whom the ankle was affected. In one patient the mass felt like localized effusion, while in another in whom the knee was affected it felt smooth and cystic. In the patient with the involved elbow, it resembled thickened synovial membrane in the posterior compartment.

Leg-length discrepancy, with the long leg on the involved side, was recorded in two patients in whom the knee was affected; the difference was three fourths of an inch (1.9 centimeters) in one patient and one and one fourth of an inch (3.2 centimeters) in the other. In the patient with the involved ankle, the foot on the involved side was one centimeter shorter than the foot on the normal side. Growth phenomena were not noted in the case reports in the literature.

ROENTGENOGRAPHIC FINDINGS

Roentgenographic findings were of little value in arriving at a diagnosis. In most patients, the roentgenographic appearance was normal or was that of varying degrees of osteoporosis. In the patient with osteochondromatosis, the find-

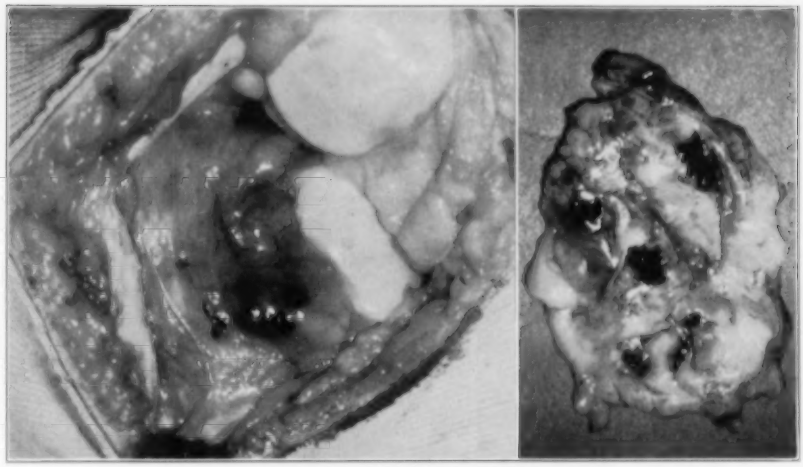

FIG. 2

Typical gross appearance. Tumor is shown lying in the subsynovial tissue of the suprapatellar pouch covered by intact synovial membrane. There is incidental chondromalacia of the patella which necessitated its removal at the time of operation. On the right is the surgical specimen after removal.

ings, of course, were commensurate with this diagnosis and that of degenerative disease of the joint. In one instance an ossicle seen in the region of the tumor itself was found at operation to be in the tumor proper. In a few patients there was increased soft-tissue density. There was a cystic region in the vicinity of the sulcus underlying the attachment of the rotator cuff to the head of the humerus in the patient whose shoulder was involved. Likewise, in the patient in whom the elbow was involved a rarefied or punched-out area was visible in the olecranon in the region where the tumor was found.

GROSS PATHOLOGICAL FEATURES

Hemangioma in the fresh state appeared as a dark grapelike mass underneath a shiny synovial covering (Fig. 2). Cutting into the mass revealed the typical spongy material characteristic of this type of tumor. Regions of isolated increased firmness occasioned by thrombosis and organization were often encountered.

Bennett and Cobey's classification of synovial hemangiomata based on type and extent of involvement assumes importance not only because it recognizes differences in clinical features but also because it has prognostic implications. They classified these tumors as diffuse or localized (pedunculated or sessile). Obviously, localized pedunculated tumors (and even sessile tumors if appropriately located) may cause characteristic symptoms by interference with joint motion, while tumors of the diffuse type more often cause only pain and periodic swelling. On the other hand, from the standpoint of prognosis, the possibility of completely removing a localized tumor understandably enhances the chance of a complete cure in such patients. In four of our series of eleven patients, the tumors were localized; complete removal was followed by apparent cure in all. Conversely, in four of the seven patients with diffuse involvement, complete removal was not possible. Three of the four had recurrence, and the fourth was last heard from only two months after surgery. The three patients whose diffuse tumors could not be removed have had no recurrence after two, two and one-half, and three years, respectively; all report normal painless function, although two have residual atrophy. Figure 1 illustrates the gross configuration and location of the tumors in the nine patients with involvement of the knee.

FIG. 3

Large cavernous spaces in subsynovial tissue containing organizing thrombi (hematoxylin and eosin, × 25).

MICROSCOPIC PATHOLOGICAL CHANGES

Histologically, hemangiomata fall into four main categories as described by Stout: capillary, cavernous, mixed cavernous and capillary, and venous. In the capillary forms, the capillaries grow in haphazard fashion. If the capillary spaces become widely dilated but still retain the simple capillary wall, the tumor is then called a cavernous hemangioma. If the vessels have relatively thick walls and contain smooth muscle cells, the tumor is called a venous hemangioma. The last feature was found in only one of the present series, and in only one was there a pure capillary picture. The remainder represented the mixed cavernous and capillary types. It was not possible, therefore, to correlate the clinical findings and end results with the histological picture. There likewise seemed to be no correlation between the clinical findings and the presence or absence of in-

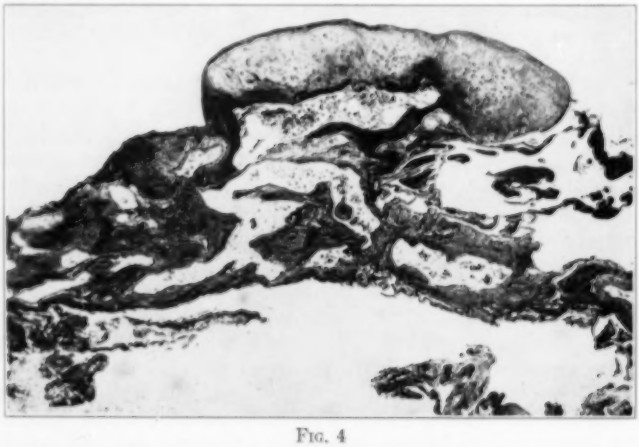

FIG. 4

Microscopic section from a patient with associated synovial chondromatosis showing intact synovial membrane at uppermost margin with an area of chondroid metaplasia directly underneath and hemangiomatous tissue beneath that (hematoxylin and eosin, × 23).

flammatory components which were marked in some cases but almost totally lacking in others.

Sites of thrombosis in various stages of organization were numerous (Fig. 3), but it was again impossible to correlate these with the clinical picture because of their ubiquity. It is probable, however, that many of the intermittent symptoms are directly related to the occurrence of thrombosis within the tumor, with consequent transient pain and swelling. In one of the patients, as previously mentioned, typical areas of cartilage formation were seen microscopically within the synovial membrane associated with hemangioma occurring in the same joint (Fig. 4).

TABLE III

FOLLOW-UP INFORMATION ON PATIENTS WITH SYNOVIAL HEMANGIOMA

Joint	Length of Follow-up	Recurrences	Condition of Joint
Diffuse tumor			
Ankle	9 yrs.	1	Surgery and roentgen therapy; still had swelling, atrophy, and obvious residual hemangioma
Elbow	9 yrs.	2	Reoperation after six years: second recurrence three years later
Knee	14 yrs.	1	Seven years postoperatively, second operation and roentgen therapy; no evident recurrence seven years after second operation
Knee	3 yrs.		Normal
Knee	2½ yrs.		Normal; still much atrophy
Knee	2 yrs.		No pain; still mild limitation of motion
Knee	2 mos.		Normal postoperative course
Localized tumor, pedunculated			
Knee	11 yrs.		Normal
Knee	1½ yrs.		Normal
Knee	1 yr.		Normal
Localized tumor, sessile			
Knee	3 yrs.		Normal

DIFFERENTIAL DIAGNOSIS

Since the diagnosis of hemangioma of the joint is seldom made preoperatively, the importance of differential diagnosis is obvious. When the clinical findings are typical, as they usually are, there should be little difficulty in realizing the probability of hemangioma. Several other diagnoses must be considered and ruled out if possible. These are: chronic infectious granuloma, internal derangement of the knee joint, hemorrhagic arthritides, pigmented villonodular synovitis, other benign tumors of the joint, and rheumatoid arthritis.

FOLLOW-UP INFORMATION AND RESULTS OF TREATMENT

Follow-up information was obtained after a reasonable postoperative period in all except two of the eleven patients (Table III). In nine patients in whom

the follow-up period ranged from one and one-half to fourteen years, there were three instances of recurrence of the tumor which necessitated further surgical treatment. In the remaining six patients no recurrence was reported after follow-up periods ranging from one and one-half to eleven years. This group of six patients included all the traced patients with localized lesions and three of the seven patients with diffuse lesions. All these patients were treated by surgical excision of the lesion; one had postoperative roentgen therapy.

The efficacy of roentgen therapy could not be evaluated in the present series because only four patients were so treated. Two of these were patients in whom incomplete removal of diffuse tumors was followed by roentgen therapy and subsequent recurrence that necessitated additional operation.

Since all of the patients followed had similar histopathological findings, these findings offer little basis for prognosis except for the theoretical expectation that a pure capillary hemangioma would be expected to respond better to roentgen therapy than tumors with cavernous components. The most important feature in the determination of prognosis seemed to be the extent of the tumor within the joint and surrounding tissue. The frequency of recurrence of diffuse tumors may be attributable to the difficulty of complete surgical removal. There is no instance of a tumor recurring after complete removal to which pedunculated and localized sessile tumors are, of course, more amenable than are diffuse tumors. In spite of postoperative roentgen therapy, two of three patients had recurrences after incomplete removal of diffuse tumors.

SUMMARY AND CONCLUSIONS

Eleven patients with hemangioma of the synovial membrane have been seen at the Mayo Clinic from 1907 through 1956. The tumor occurred in the knee in nine patients, and in the ankle and elbow, respectively, in two others. These patients represent the first reported instances of involvement of these joints. The results of this study suggest that synovial hemangioma should be suspected if the patient is young, symptoms are of long duration, pain and swelling occur intermittently (usually without obvious cause), and the patient presents an exquisitely tender mass that feels soft and doughy, increases in size when in a dependent position, and decreases in size on elevation.

Prognosis following surgical excision of these tumors appears to depend on the feasibility of complete excision of the tumor and not on any inherent pathological characteristics of the tumor itself.

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Xeroroentgenography

An Evaluation of its Use in Diseases of the Bone and Joints of the Extremities *

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Xeroroentgenography is the recording of roentgen images with a standard roentgenographic camera by a photo-electric process rather than the photochemical one used in conventional roentgenography. The technical details of xeroroentgenography have been described by McMaster and Wenk, Roach and Hilleboe, and Oliphant. An electrostatic image of the size, shape, and radiodensity of an interposed object is produced on a xeroplate which is a metallic plate coated with a semi-conductor such as selenium. The xeroplate is fitted to a wooden plate-holder and protected from light by a coverslide. The image is made visible by placing finely divided powder granules on the charged pattern of the xeroplate. The processing unit is small and can be placed on a wheeled stretcher so that it can be moved easily. This method requires no x-ray film or darkroom, and the whole procedure usually takes less than fifty seconds.

The speed of effectiveness of xeroplates has been steadily improved so that at the present time it is between that of Eastman Blue Brand film in cardboard holders and the same film in cassettes using Patterson Par Speed intensifying screens. Roach and Hilleboe, in their comparative study of roentgen images of a very fine bronze wire screen of known size, found the resolving powder to be excellent. A study of aluminum stepwedges showed a wider latitude in the xeroplates than in the Eastman Blue Brand film. Comparative studies were made by

* This investigation was supported by a research grant from the Easter Seal Foundation.

FIG. 1-A

FIG. 1-B

Fig. 1-A: Conventional roentgenogram of a severely comminuted fracture of the distal portion of the radius in a man fifty-one years old. Juxta-articular cysts are present in several carpal bones. (Exposure: focal-film distance, forty inches; non-screen, non-Bucky; 100 mas; 56 KVP.)

Fig. 1-B: The xeroroentgenogram shows the accentuation of fine detail bordering the sharply defined cortical margins of the bone. (Exposure: focal-film distance, forty inches; non-screen, non-Bucky; 60 mas; 56 KVP.)

FIG. 2-A

FIG. 2-B

Fig. 2-A: Conventional roentgenogram of the capitellum and head of the radius of a patient with tuberculosis of the elbow. (Exposure: focal-film distance, forty inches; non-screen, non-Bucky; 100 mas; 60 KVP.)

Fig. 2-B: Xeroroentgenogram is helpful in illustrating the complete erosion of the subchondral cortex which was later verified by biopsy. (Exposure: focal-film distance, forty inches; non-screen, non-Bucky; 60 mas; 60 KVP.)

the authors [1,2] of bone specimens of adult and embryonic bone. Occasional examples showing some of the results obtained in clinical use were published [4,7,9].

The present study is a clinical evaluation of xeroroentgenography as applied to the bones and joints of the extremities, where a technique similar to that used

FIG. 3

The difference between the conventional roentgenogram (exposure: focal-film distance, forty inches; par speed intensifying; 10 mas; 65 KVP) and the powder image of the xeroroentgenogram (exposure: focal-film distance, forty inches; screens, non-Bucky; 70 mas; 65 KVP) are evident in the anteroposterior and lateral views of this knee. There is a fracture of the anterior part of the tibial spine. Soft-tissue details in the xeroroentgenograms show a posterior bulging of the joint capsule, the quadriceps and patellar tendons, and some of the fascial planes.

in conventional roentgenography can be employed. The heavier parts of the body such as the skull, abdomen, pelvis, and lumbar spine were not studied since they require exposures considerably in excess of that needed for standard filming. One hundred patients admitted to the Albany Hospital with pain or disability in an extremity had both xeroroentgenograms and conventional roentgenograms made to show the involved bone or joint. The former were recorded photographically by the use of thirty-five-millimeter type F Kodachrome film and the resulting photographs enlarged, whereas the latter were reduced so that the roentgen images by both techniques were identical in size. Xeroroentgenograms, conventional roentgenograms, and microscopic slides were made of pathological specimens obtained in some cases.

DISCUSSION

The fine definition and contrast gradation is greater in the xeroroentgenogram

FIG. 4-A

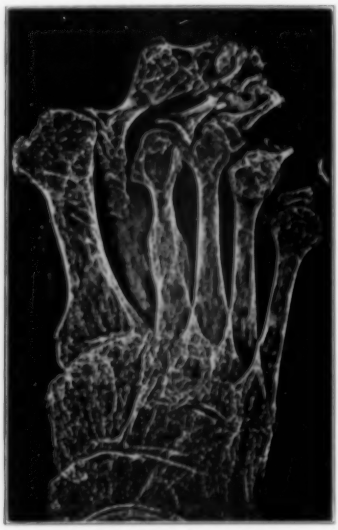

FIG. 4-B

Fig. 4-A: Conventional roentgenogram of the foot of a woman, seventy-eight years old, suffering from peripheral neuritis secondary to diabetes. (Exposure: focal-film distance, forty inches; non-screen, non-Bucky; 100 mas; 62 KVP.)

Fig. 4-B: The fine detail along the margins of extremely osteoporotic bone is well illustrated in the xeroroentgenogram. (Exposure: focal-film distance, forty inches; non-screen, non-Bucky; 70 mas; 62 KVP.)

FIG. 5-A

FIG. 5-B

Fig. 5-A: Conventional roentgenograms of a Charcot joint. (Exposure: focal-film distance, forty inches; par speed screens, Bucky; 60 mas; 70 KVP.)

Fig. 5-B: The margins and the small detached fragments of bone are more easily identified in the xeroroentgenogram despite the sclerotic bone. (Exposure: focal-film distance, forty inches; par speed screens, Bucky; 150 mas; 70 KVP.)

than in the conventional roentgenogram in studies of both bone and soft tissue. Much of the contrast gradation is enhanced by a slight exaggeration of sharp margins due to a slight increase of powder on one side and a slight decrease on the other side of the boundary of the electrostatic charge on the xeroplate (Fig. 1-B).

FIG. 6-A

FIG. 6-B

Fig. 6-A: Conventional air injection arthrogram of the normal knee. (Exposure: focal-film distance, forty inches; par speed intensifying screens, non-Bucky; 10 mas; 65 KVP.)

Fig. 6-B: The soft-tissue details stand out more clearly in the xeroroentgenograms. (Exposure: focal-film distance, forty inches; par speed intensifying screens, non-Bucky; 70 mas; 65 KVP.)

FIG. 7-A

Figs. 7-A and 7-B: The difference in the pattern of tumor bone and the irritative new-bone formation at the upper margin of an osteogenic sarcoma is interesting in the xeroroentgenogram. (Exposure: focal-film distance, forty inches; par speed intensifying screens, Bucky; 50 mas; 60 KVP.)

FIG. 7-B

FIG. 7-C

The xeroroentgenogram and pathological section of the specimen following biopsy and amputation verify the extent of the tumor as seen in Fig. 7-A. (Exposure: focal-film distance, forty inches; par speed intensifying screens, Bucky; 100 mas; 75 KVP.)

When a sharp margin is absent, as in an erosion of the subchondral cortex due to tuberculous granulations (Figs. 2-A and 2-B), the lack of the fine definition of the cortex at the joint margin is evident.

With the calcium carbonate powder now used one obtains an image of low contrast. This is one in which, unlike that obtained by using conventional film, both the radiodense and radiolucent portion of the image are shown. In a xeroroentgenogram of a knee (Fig. 3), not only the fracture but also the margins of the quadriceps muscle, joint capsule, fat pads, and patellar tendon are visible. The injection of air into a joint further enhances the visualization of soft tissues (Fig. 6-B). The margins of bones which are extremely osteoporotic (Fig. 4-B) or sclerotic (Fig. 5-B) are more clearly defined than in the conventional roentgenograms. New-bone formation in the soft tissue (Fig. 7-A) is often more apparent in the xeroroentgenogram.

Artifacts, in the form of small spots on the xeroplates, were often present. These were small clumps of powder granules and were more frequent in xeroplates in which the charge was excessive and in older and more defective xeroplates. They were not confused with bone or soft tissue.

CONCLUSIONS

1. Xeroroentgenography is an effective means of recording roentgen images of the bones and joints of the extremity.

2. The accentuation of fine definition and contrast gradation in examination of both bone and soft tissue is an aid in the study of diseases of the bones and joints of the extremities.

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Biomechanical Studies on the Lumbar Spine and Pelvis*

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Injury of the lumbar spine is rather frequent in both civilian and military life. The injury, especially disc herniation, may arise from bending of the spine, particularly flexion, or from the application of a force to the spine.

The present study was undertaken in order to determine, under controlled experimental conditions, the following phenomena: the relation between load and amount of deflection in compression and transverse bending of the lumbar spine and the energy-absorbing capacity of the lumbar spine. The latter is particularly important because back injuries occurring in accidents generally arise from a suddenly applied external force. Consequently, the injury produced is a function of the energy absorbed and its rate of absorption.

TABLE I

Cadaver	Age	Sex	Race	Cause of Death	Condition of Specimen
1920	85	M	W	Cerebral hemorrhage	Embalmed
1924	60	M	W	Carcinoma of hard palate	Embalmed
2176	57	M	W	Renal acidosis	Embalmed
2221	65	M	N	Bronchopneumonia	Embalmed
2257	82	M	W	Coronary thrombosis	Embalmed
2279	82	M	W	Carcinomatosis	Embalmed
2310	73	M	W	Carcinoma of larynx	Embalmed
2346	47	M	W	Chronic nephritis	Embalmed
2403	75	M	W	Mesenteric thrombosis	Embalmed
2421	75	M	W	Gastro-intestinal hemorrhage	Embalmed
2429	60	M	W	Acute leukaemia	Embalmed
2533	67	M	W	Carcinoma of lung	Embalmed
2560	61	M	N	Acute myocardial infarction	Unembalmed
2572	64	M	W	Subarachnoid hemorrhage	Unembalmed
2625	59	M	W	Carcinoma of esophagus	Embalmed
2650	54	M	W	Acute pulmonary oedema	Embalmed
J. M.	58	M	W	Pulmonary tuberculosis	Unembalmed
E. P.	37	M	W	Uraemia and renal and pulmonary tuberculosis	Unembalmed
H. O'B.	51	M	W	Carcinoma of lung	Unembalmed
2537	69	M	W	Rheumatic heart disease, pulmonary infarct, arteriosclerosis	Unembalmed

The clinical literature on back injury is extensive. Recently there have also been several studies on the physical properties and the mechanical behavior of the lumbar discs by Virgin, Hirsch, Hirsch and Nachemson, Evans, and Brown, Hansen and Yorra. However, except for a brief preliminary discussion, given by Evans [2],

* This investigation was supported by a Research Contract with the Aero Medical Laboratory, United States Air Force, and (in part) by Research Grant A-377 (C8) from the National Institutes of Health.

of the methods and the results of two of the tests in the present series, the authors know of no previous load-deflection, energy-absorption, and bending-moment studies on the intact lumbar spine and pelvis.

MATERIAL AND METHODS

The material used in the study (Table I) consisted of the intact lumbar spine and pelvis of fourteen embalmed and six unembalmed adult human male cadavera. The embalmed specimens were kept in embalming fluid until tested while the unembalmed specimens were kept in the deep freeze and only removed a short time before testing. During this time some thawing occurred so that the specimens were wet when tested.

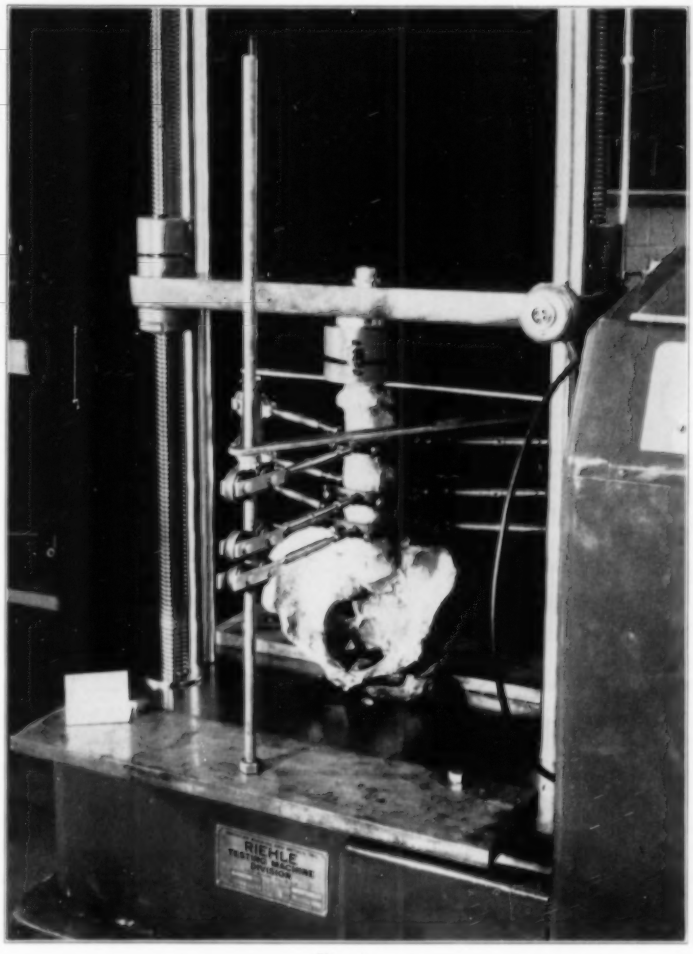

FIG. 1

Apparatus for holding specimen during vertical-loading tests.

Two general types of tests were performed: the first in which the load was applied to the vertebral column parallel with its long axis and the second in which the load was applied to the vertebral column transverse or perpendicular to its long axis. For each type of test, a special apparatus was designed for holding the specimen.

The apparatus for holding the specimen in the vertical position for the first type of test is seen in Figure 1. In these tests the specimen rested upon the ischial tuberosities of the pelvis in the same manner as occurs when a person is sitting down. The apparatus was then adjusted so that the lumbar spine was straight. This orientation of the specimen was chosen because it approximates the condition of the lumbar spine of a pilot in an ejection seat just before the release mechanism is activated and the pilot is ejected from the plane. The specimens were tested in a Riehle 5,000-pound capacity universal testing machine calibrated to an accuracy of 1 per cent.

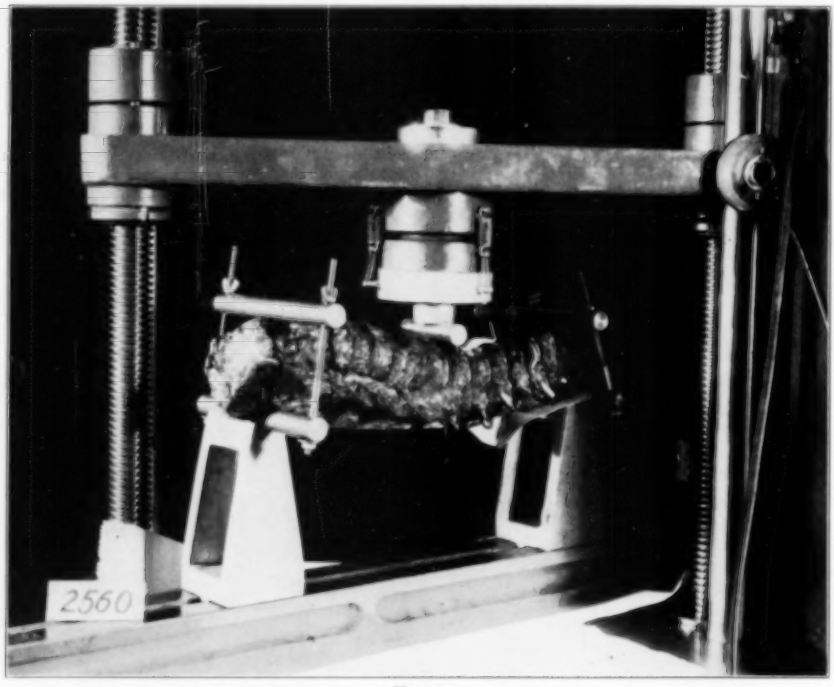

FIG. 2

Apparatus for holding specimen during bending tests.

In order to study the influence of bending upon the spine, a second apparatus (Fig. 2) was designed. In these tests the pelvis was removed and only the lumbar spine and sacrum were used. The specimen to be tested was placed on supports which were adjustable with respect to the distance between them so that varying lengths of segments of the vertebral column could be tested. The bending was produced by applying a load to a solid steel rod placed across the vertebral column between the supports. By altering the position of the column on the supports the influence of extension, flexion and abduction, or lateral bending of the vertebral column could be studied. The entire apparatus was then placed on the table of the Riehle testing machine and the load applied to the bar. The testing machine was equipped with a stress-strain recorder so that a load-deflection curve was automatically drawn for each specimen during a test.

In each test the maximum load was taken to be the point beyond which the specimen could take no more load as indicated by the falling off of the load registered on the dial of the testing machine. By measuring with a compensating polar planimeter the area beneath a load-deflection curve, the energy (inch pounds) absorbed by the specimen during a test could be determined.

RESULTS OF THE TESTS

In analyzing the data obtained from the tests the following factors must be considered: the condition of the specimen (embalmed or unembalmed) and the anatomical parts actually tested. Embalming tends to harden and stiffen the specimen which would influence its load-bearing capacity, its deflection under load, and the amount of energy it absorbed.

The anatomical parts tested, especially the number of vertebrae, must be considered because the vertebral column is a jointed, multiarticulated tube held together by joint capsules and ligaments. Consequently, the length of the segment of the vertebral column tested, in addition to the pelvis, influences the deflection and energy-absorbing capacity of the specimen. Each of these factors will be considered in evaluating the results of the tests.

TABLE II

DEFLECTIONS AND ENERGY ABSORBED BY THE LUMBAR SPINE AND PELVIS UNDER VERTICAL LOADING

Cadaver	Age	Sex	Race	Specimen Condition	Parts Tested*	Loading Speed (*Inch per Minute*)	Maximum Load (*Pounds*)	Deflection (*Inches*)	Energy Absorbed (*Inch Pounds*)
1920	85	M	W	Embalmed	P + L1-L5	0.0475	738	0.75	213
1924	60	M	W	Embalmed	P + L2-L5	0.0475	1350	1.30	1321
2176	57	M	W	Embalmed	P + L1-L5	0.0475	1002	0.90	1147
2221	65	M	N	Embalmed	P + L1-L5	0.070	890	0.86	405
2257	82	M	W	Embalmed	P + L1-L5	0.070	978	1.21	595
2310	73	M	W	Embalmed	P + L1-L5	0.070	625	1.45	496
2346	47	M	W	Embalmed	P + L1-L5	0.070	610	1.77	725
2429	60	M	W	Embalmed	P + L1-L5	0.070	862	1.31	641
J. M.	58	M	W	Unembalmed	P + T12-L5	0.0475	690	2.38	1013
E. P.	37	M	W	Unembalmed	P + T12-L5	0.070	652	1.23	513
H. O'B.	51	M	W	Unembalmed	P + T12-L5	0.0475	290	1.06	174

*P, pelvis; L, lumbar vertebra; T, thoracic vertebra.

Vertical Loading

More specimens (eight from embalmed and three from unembalmed bodies) were tested under vertical loading than in any other orientation. The reason for doing so is because injuries of the lumbar spine, including disc herniations, have been reported as occurring in pilots ejected from airplanes in emergency escape. In such ejections, the propulsive force is applied to the bottom of the ejection seat in a direction parallel with the long axis of the body. Therefore, since this research was supported primarily by the Air Force, a similar direction of loading the pelvis and vertebral column was employed in most of our tests. Table II summarizes the data obtained in these tests. It must be remembered that each value is the result of testing an intact pelvis and a segment of the vertebral column.

From Table II it is seen that all but three of the specimens were obtained from embalmed bodies. Furthermore, all but one (cadaver 1924) of these specimens consisted of the intact pelvis and all five lumbar vertebrae and discs. The three specimens from unembalmed bodies consisted of the intact pelvis plus six vertebrae (twelfth thoracic and all the lumbar vertebrae and discs).

Comparison of the results obtained from testing embalmed and unembalmed specimens revealed the following differences. In the embalmed specimens the average maximum load was 882 pounds (610 to 1350 pounds) but in the unembalmed specimens it was only 544 pounds (290 to 690 pounds). The embalmed specimens absorbed an average of 594 inch pounds of energy (213 to 1321 inch pounds) which

was only slightly greater than that, 567 inch pounds (174 to 1013 inch pounds), absorbed by the unembalmed specimens. The average deflection of the embalmed specimens was 1.19 inches (0.98 to 1.32 inches) while the unembalmed specimens had an average deflection of 1.56 inches (1.23 to 2.38 inches).

The greater average deflection shown by the unembalmed specimens is partially related to the fact that a longer segment of the vertebral column (six vertebrae and discs), in addition to the pelvis, was tested than was true for the embalmed specimens (five vertebrae, discs, and the pelvis). Consequently, the distance over which deflection or bending could occur was greater in the unembalmed than in the embalmed specimens. The addition of a single vertebra was not sufficient to account for all of the additional deflection. An additional factor was that the unembalmed specimens had not had an opportunity to become as dry as the embalmed ones, which were also stiffened by the embalming.

TABLE III

BENDING MOMENT, DEFLECTIONS, AND ENERGY ABSORPTION DURING BENDING OF THE HUMAN SPINE

Cadaver	Age	Sex	Race	Parts Tested†	Type of Bending	Loading Speed (*Inch per Minute*)	Maximum Load (*Pounds*)	Bending Moment (*Inch Pounds*)	Deflection (*Inches*)	Energy Absorbed (*Inch Pounds*)
2403*	75	M	W	S + L1-L5	Ant.	0.10	615	769	1.050	304
2421*	75	M	W	S + L1-L5	Ant.	0.10	495	618	1.10	295
2537	69	M	W	S + T5-L5	Ant.	0.15	450	1012	2.025	437
2560	61	M	N	S + T7-L5	Ant.	0.15	220	770	1.96	185
2572	64	M	W	S + T5-L5	Ant.	0.20	200	700	1.58	173
2279*	82	M	W	S + L1-L5	Lat.	0.15	495	618	0.83	253
2533*	67	M	W	S + L1-L5	Lat.	0.15	250	312	1.30	213
2625*	59	M	W	S + L1-L5	Lat.	0.15	430	537	1.53	391
2650*	54	M	W	S + L1-L5	Lat.	0.15	335	418	1.36	244

*Embalmed. † S, sacrum; L, lumbar vertebra; and T, thoracic vertebra.

The age of the individuals from whom the specimens were obtained should also be considered. Among the embalmed specimens six of them were obtained from individuals sixty or more years of age while only two specimens were from younger individuals. The specimens from the older individuals supported an average maximum load of 907 pounds with an average deflection of 1.14 inches and an average absorption of 611 inch pounds of energy. The two embalmed specimens from individuals less than sixty years of age had an average maximum load of 806 pounds, an average deflection of 1.34 inches, and an average absorption of 936 inch pounds of energy. The corresponding average values for the three unembalmed specimens, all of which were taken from individuals less than sixty years of age, have been given previously.

Slightly different values were obtained when specimens from individuals less than sixty years of age were considered without regard as to whether they came from embalmed or unembalmed bodies. Under this condition the average values were 649 pounds for maximum load, 1.47 inches for deflection, and 714 inch pounds for energy. Although the specimens from individuals less than sixty years of age supported a smaller maximum load than did the specimens from individuals sixty or more years of age, the former specimens exhibited greater deflection (flexibility) and energy-absorbing capacity than did the latter specimens. The greater flexibility and energy-absorbing capacity of the specimens from younger individuals should serve as factors for safety as far as spinal injuries from vertical loading are concerned. When the data presented in Table II were plotted against the age of the individual from whom the specimen was obtained, arranged in order from

younger to older, no consistent trends or evidence of a positive correlation between age and the maximum load, the deflection, or the energy absorbed was found. Even among the embalmed specimens consisting of the same anatomical parts (pelvis and all five lumbar vertebrae and discs) no apparent relationship between age and maximum load, deflection, or energy-absorbing capacity was evident. Thus, age alone appears to have relatively little influence on the biomechanical behavior of the lumbar spine and pelvis under static vertical loading.

Examination of the load-deflection curves for the embalmed specimens consisting of the pelvis and all the lumbar vertebrae and discs (Figs. 3 through 9) shows that in most of them the load increased more rapidly than the deflection. In only three specimens, cadavera 2310, 2346, and E. P. (unembalmed), did the increase in load and deflection more nearly approximate each other although the former still increased somewhat more rapidly than the latter (Figs. 7, 8, and 11). In cadaver H. O'B. (Fig. 12) the increase in load and deflection were almost equal for most of the test although toward the end deflection increased more rapidly than load.

TABLE IV

AVERAGE VALUES AND THE RANGE OF VARIATION IN THE MAXIMUM LOAD SUPPORTED, DEFLECTION, ENERGY ABSORBED, AND BENDING MOMENT IN THE LUMBAR SPINE

Parts Tested*	Condition of Specimen	Number of Tests	Maximum Load (*Pounds*)	Deflection (*Inches*)	Energy Absorbed (*Inch Pounds*)	Bending Moment (*Inch Pounds*)
			Vertical Loading			
P + L1-L5	Embalmed	7	815	1.18	603	
			(610 - 1002)	(0.75 - 1.77)	(213 - 1147)	
P + T12-L5	Unembalmed	3	544	1.56	566	
			(290 - 690)	(1.06 - 2.38)	(174 - 1013)	
			Anterior Bending			
S + L1-L5	Embalmed	2	560	1.08	300	694
			(495 - 625)	(1.050 - 1.10)	(295 - 304)	(618 - 769)
S + T5-L5	Unembalmed	2	325	1.80	305	856
			(200 - 450)	(1.58 - 2.025)	(173 - 437)	(700 - 1012)
S + T7-L5	Unembalmed	1	220	1.96	185	770
			Lateral Bending			
S + L1-L5	Embalmed	4	377	1.26	275	471
			(250 - 495)	(0.83 - 1.53)	(213 - 391)	(312 - 618)

* P, pelvis; L, lumbar vertebra; S, sacrum; and T, thoracic vertebra.

In only one test, cadaver J. M. (Fig. 10), did the deflection increase more rapidly than the load. This specimen was obtained from an unembalmed body of a white man, fifty-eight years of age, and was the most flexible of any specimens tested. The other two specimens from unembalmed bodies, E. P. and H. O'B. (Figs. 11 and 12) were also more flexible than the specimens from embalmed bodies. The greater stiffness of the specimens from embalmed bodies may be the result of the hardening effect of the formalin used in the embalming fluid and also because they were more dessicated than the specimens from unembalmed bodies.

Most of the deflections recorded in these tests occurred in the pelvis because the vertebral column itself was prevented from bending to any appreciable extent by the apparatus (Fig. 1) used to hold the specimen in position during a test.

Transverse Loading (Bending Tests)

The nine specimens (Table III) used in this series of tests were loaded like

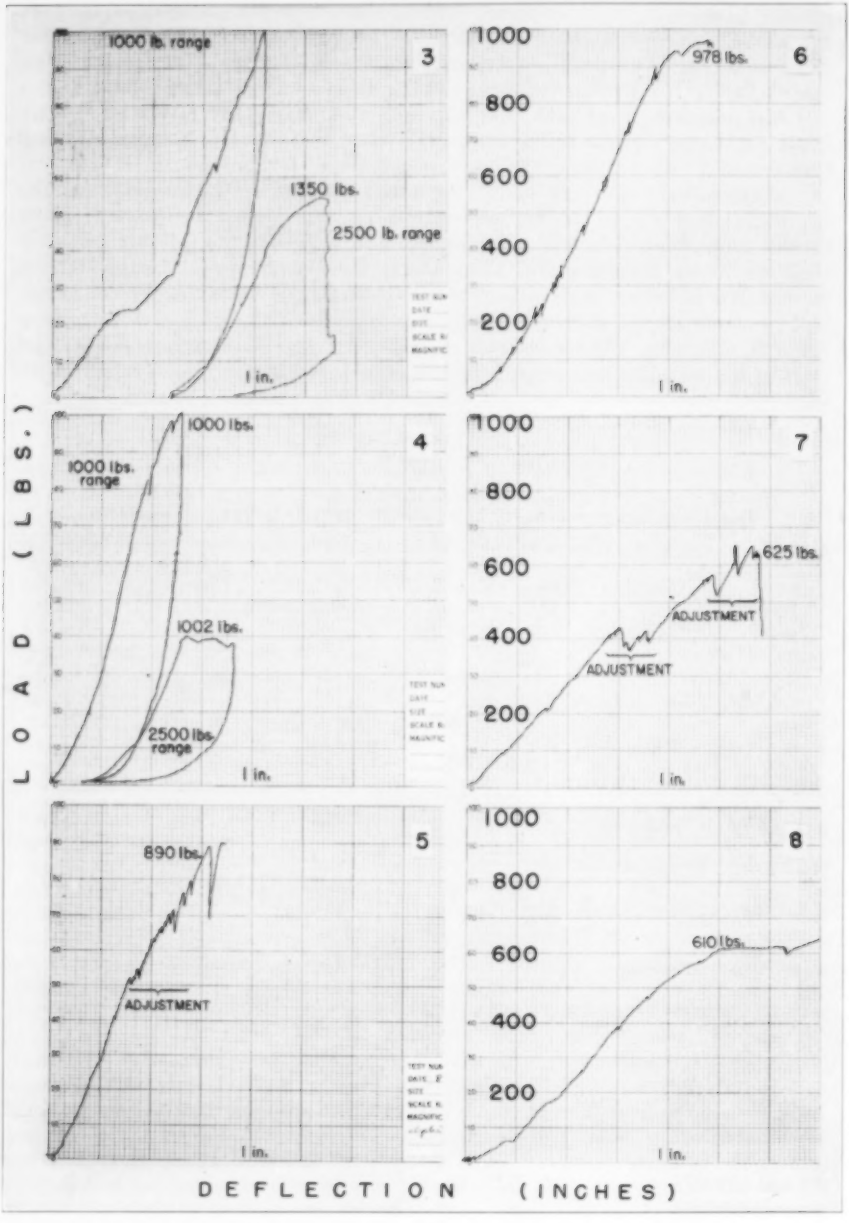

PLATE 1

Load-deflection curves for specimens of the lumbar spine and pelvis tested by static vertical loading.

Fig. 3: Embalmed specimen from a white man sixty years of age (1924). Energy absorbed, 1321 inch pounds. Because of the magnitude of the load supported by this specimen, the testing machine had to be changed from the 1000 to the 2000-pound range.

Fig. 4: Embalmed specimen from a white man fifty-seven years of age (2176). Energy absorbed, 1147 inch pounds. This specimen showed slight failure at 982 pounds, but did not completely fail before the 1000-pound range was reached. Therefore, the load was removed and the 2500-pound range of the testing machine was used on the second test.

Fig. 5: Embalmed specimen from a Negro man sixty-five years of age (2221). Energy absorbed, 405 inch pounds. *Adjustment* indicates the place where the specimen started to slip so that the apparatus had to be adjusted before continuing the loading.

Fig. 6: Embalmed specimen from a white man eighty-two years of age (2257). Energy absorbed, 595 inch pounds.

Fig. 7: Embalmed specimen from a white man seventy-three years of age (2310). Energy absorbed, 496 inch pounds. The specimen slipped twice during the test so that adjustments had to be made.

Fig. 8: Embalmed specimen from a white man forty-seven years of age (2346). Energy absorbed, 725 inch pounds.

a beam (Fig. 2). By rotating the spine, so that the load could be applied to the anterior or the lateral aspect of it, bending in an anteroposterior or in a frontal plane, respectively, could be simulated. Five specimens were tested in anterior bending and four in lateral bending. Because of the variation in the length of the vertebral column tested and in the distance between the supports, the results of these tests will be described separately.

In the anterior-bending tests of embalmed specimens 2403 and 2421 the supports, at the first and fifth lumbar vertebrae, were five inches apart while the load was applied to the anterior aspect of the body of the third lumbar vertebra at a speed of 0.10 inch per minute. In spite of the similarity in the condition of the specimens and of the tests there was considerable variation in the results (Table III).

The three other specimens tested in anterior bending were from unembalmed bodies and consisted of longer segments of the vertebral column. Two of them, 2537 and 2572, were composed of the sacrum and all of the lumbar vertebrae, as well as the lower eight thoracic vertebrae. In specimen 2537, the supports were nine inches apart and the load was applied to the second lumbar vertebra. Specimen 2572 had the supports fourteen inches apart and was loaded at the twelfth thoracic vertebra. The supports were also fourteen inches apart in specimen 2560 but the load was applied to the first lumbar vertebra.

It is thus evident that the span or distance in which bending could occur was considerably greater in the unembalmed than in the embalmed specimens. The effect of this greater span (Table IV) is evident in the greater average deflection (1.80 inch) of the unembalmed specimens as compared with the deflection (1.08 inch) occurring in the embalmed specimens. The average amount of energy absorbed was 300 inch pounds and 305 inch pounds for the embalmed and unembalmed spines, respectively.

For comparison of the results obtained in the bending tests, in which the specimens were loaded like a beam, the *bending moment*, which is a measure of the magnitude of the bending, was computed. Under the conditions of loading and of support used in the tests the bending moment (inch pounds) is equal to the product of the maximum load and the distance between the supports (span) divided by four.

From the data in Table III, it is seen that, except for specimen 2537, the bending moment in anterior flexion was quite similar in the embalmed and unembalmed specimens. Thus, the average bending moment was 694 inch pounds (618 to 769) for the embalmed specimens (2403 and 2421) and 735 inch pounds (700 to 770) for the unembalmed specimens (2560 and 2572). The reason for the much greater bending moment in specimen 2537 is unknown. The embalmed specimens consisted entirely of lumbar vertebrae and discs and sacrum while the unembalmed specimens, in addition to these parts, also included some thoracic vertebrae and discs. Perhaps the greater bending moment in the unembalmed specimens, especially in specimen 2537, reflects some inherent differences in the bending moment of the lumbar and thoracic regions of the spinal column. Too few specimens were tested for final conclusions to be drawn concerning the effect of embalming on the bending moment.

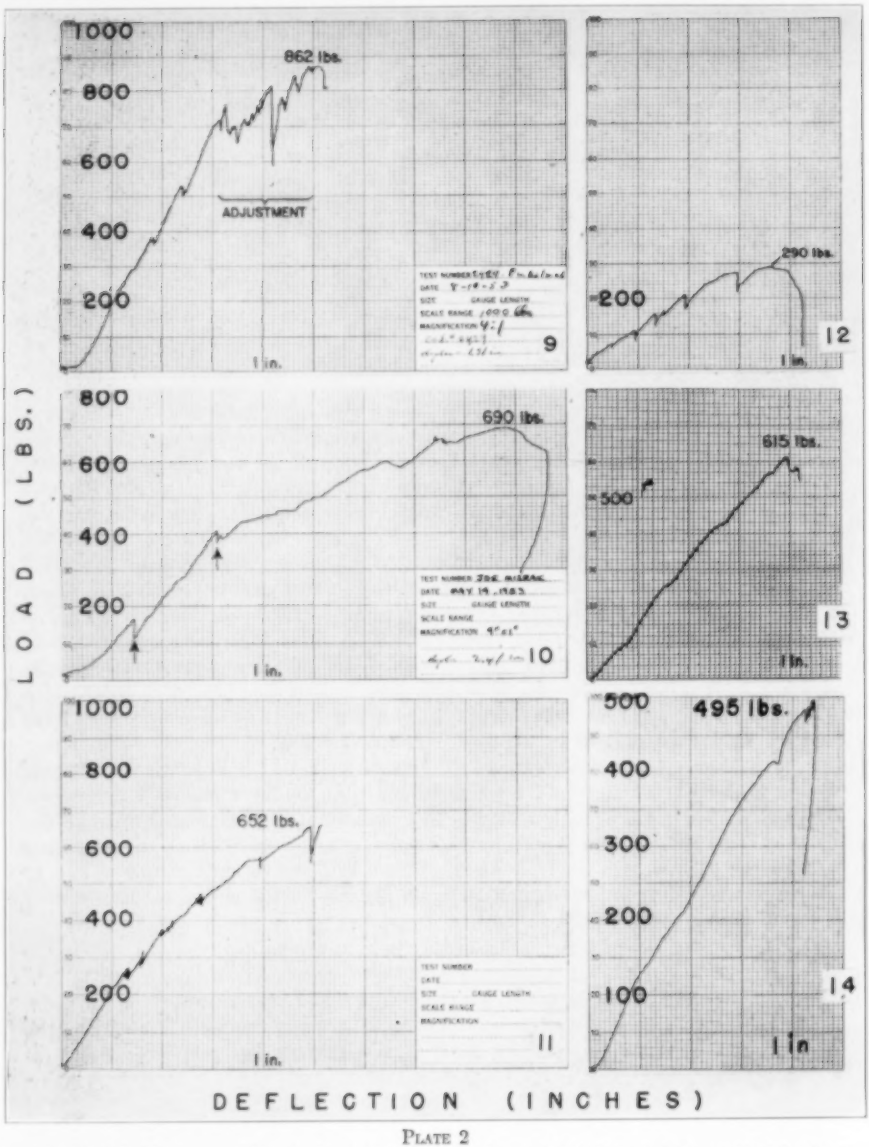

PLATE 2

Load-deflection curves for specimens of lumbar spine and pelvis tested by vertical loading (Figs. 9, 10, 11, and 12) and of lumbar spine tested by anterior bending (Figs. 13 and 14).

Fig. 9: Embalmed specimen from a white man sixty years of age (2429). Energy absorbed, 641 inch pounds. The specimen slipped during the test so that an adjustment had to be made before continuing.

Fig. 10: Unembalmed specimen from a white man fifty-eight years of age (J. M.). Energy absorbed, 1013 inch pounds.

Fig. 11: Unembalmed specimen from a white man thirty-seven years of age (E. P.). Energy absorbed, 513 inch pounds.

Fig. 12: Unembalmed specimen from a white man fifty-one years of age (H. O'B.). Energy absorbed, 174 inch pounds.

Fig. 13: Embalmed specimen from a white man seventy-five years of age (2403). Energy absorbed, 304 inch pounds; bending moment, 769 inch pounds.

Fig. 14: Embalmed specimen from a white man seventy-five years of age (2421). Energy absorbed, 495 inch pounds; bending moment, 618 inch pounds.

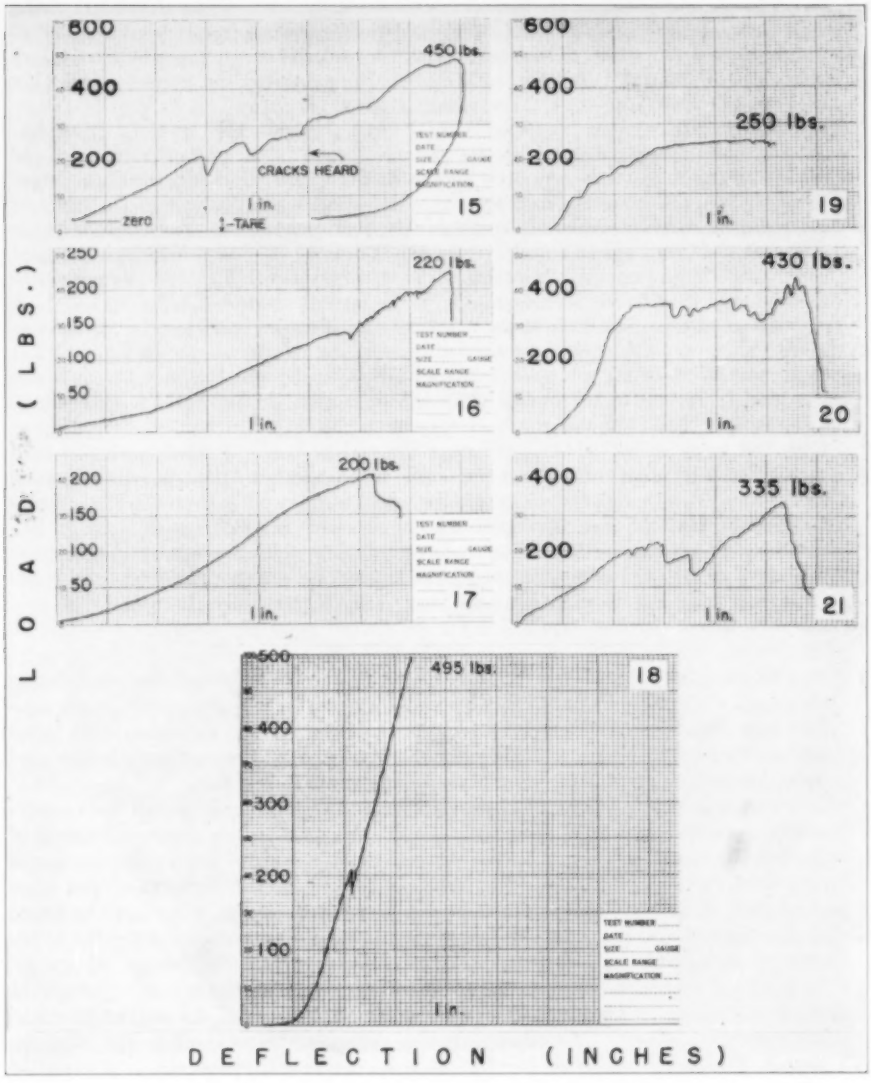

PLATE 3

Load-deflection curves for specimens of lumbar spine tested by anterior bending (Figs. 15, 16, and 17) and by lateral bending (Figs. 18, 19, 20, and 21).

Fig. 15: Unembalmed specimen from a white man sixty-nine years of age (2537). Energy absorbed, 437 inch pounds; bending moment, 1012 inch pounds.

Fig. 16: Unembalmed specimen from a Negro man sixty-one years of age (2560). Energy absorbed, 185 inch pounds; bending moment, 770 inch pounds.

Fig. 17: Unembalmed specimen from a white man sixty-four years of age (2572). Energy absorbed, 173 inch pounds; bending moment, 618 inch pounds.

Fig. 18: Embalmed specimen from a white man eighty-two years of age (2279). Energy absorbed, 253 inch pounds; bending moment, 618 inch pounds.

Fig. 19: Embalmed specimen from a white man sixty-seven years of age (2533). Energy absorbed, 213 inch pounds; bending moment, 312 inch pounds.

Fig. 20: Embalmed specimen from a white man fifty-nine years of age (2625). Energy absorbed, 391 inch pounds; bending moment, 537 inch pounds.

Fig. 21: Embalmed specimen from a white man fifty-four years of age (2650). Energy absorbed, 244 inch pounds; bending moment, 418 inch pounds.

The slope of the load-deflection curves for anterior bending showed that the load increased more rapidly than the deflection in spines from embalmed bodies (Figs. 13 and 14) while the reverse behavior occurred in the unembalmed spines (Figs. 15, 16, and 17). Specimen 2537 (Fig. 15) exhibited the greatest deflection (Table III) found in any of the bending tests.

The four specimens tested by lateral flexion (Table III) were all from embalmed bodies and consisted of the sacrum and all five lumbar vertebrae and discs. During a test the supports, at the first and fifth lumbar vertebrae, were five inches apart while the load was applied to the lateral aspect of the body of the third lumbar vertebra at a speed of 0.15 inch per minute. The average value and range of variation (Table IV) was 471 inch pounds (312 to 618 inch pounds) for the bending moment, 1.26 inches (0.83 to 1.53 inches) for deflection, and 275 inch pounds (213 to 391 inch pounds) for the energy absorbed.

Although the condition of the specimens and loading were similar, there was more variation in the shape of the load-deflection curves (Figs. 18 through 21) than in anterior-bending tests. Specimen 2279 (Fig. 18) was the only one in which the load increased more rapidly than the deflection throughout the entire test. In specimen 2625 (Fig. 20) the load increased more rapidly than the deflection at first, but later it leveled off until near the end of the test when a rise in load occurred. A leveling off toward the end of the test also occurred in specimen 2533 (Fig. 19) although the deflection increased more rapidly than the load during the first part of the test. The load-deflection curve for specimen 2650 (Fig. 21) exhibited two peaks, with a valley between, during which the load and deflection increased at approximately the same rate. However, the general slope of the curve indicated that deflection, as a whole, increased more rapidly than load.

DISCUSSION

The results of the vertical-loading tests (Table IV) showed that embalming increased the average maximum load and energy which the specimen could support and absorb but decreased the magnitude of the average deflection. The latter occurred in spite of the fact that the unembalmed specimens were longer and provided a greater distance through which deflection could occur.

The only previous investigations known to the authors in which the energy-absorbing capacity of the vertebral column was studied are the experiments of Ruff, who determined the energy absorbed by segments of fresh spinal columns subjected to vertical loading in a testing machine. In one segment of the spine consisting of six vertebrae (from the tenth thoracic to the third lumbar) he found that a load of 690 kilograms was combined with a deformation of twelve millimeters, and an absorption of 4.5 kilogram meters (390 inch pounds) of energy. In a second specimen composed of seven vertebrae (from the seventh thoracic to the first lumbar) a load of 540 kilograms, a deformation of 4.5 millimeters, and an absorption of only 1.4 kilogram meters (121 inch pounds) of energy were reported. The energy absorbed by the first specimen is within the range of variation (Table II) found by the authors in vertical loading but the second specimen absorbed less energy than any of the authors' specimens.

It was also found that the bending moment (Table IV) in the anterior-bending tests, regardless of the condition (embalmed or unembalmed) of the specimen, is greater than in the lateral-bending tests. The specimens tested by lateral bending were from embalmed bodies and consisted of the same anatomical parts (sacrum and all of the lumbar vertebrae and discs) as the embalmed specimens tested in anterior bending. However, the latter had an average bending moment of 694 inch pounds as compared with an average of only 471 inch pounds for the former specimens. The embalmed specimens tested by lateral bending had a greater average deflection (Table IV) than similar specimens tested by anterior bending. The greatest average amount of energy was absorbed during vertical loading and the least during lateral bending.

Embalming apparently had little effect on the energy-absorbing capacity of specimens tested by anterior bending but reduced the average amount of the deflection. The unembalmed specimens tested by anterior bending had the greatest average deflection of all specimens. A partial explanation for this is that they were longer than any of the embalmed specimens and had a greater distance between the supports. Consequently, they had a longer span through which deflection could occur. An additional factor is that embalming hardens and stiffens the specimen.

Comparison of the load-deflection curves (Figs. 3 through 9 and 13 through 17) for embalmed specimens reveals that the load increased more rapidly than the deflection in most of the specimens tested by vertical loading and all of the specimens tested by anterior bending. In most of the specimens tested by lateral bending the load-deflection curves (Figs. 18 through 21) tended to level off into a plateau toward the end of the test. This indicated that load increased more rapidly than deflection for the first part of the test but later the reverse occurred. The load-deflection curves for lateral bending were more irregular in form than those found for anterior bending and many of the ones for vertical loading. Because of the hardening and stiffening effect of embalming, the load-deflection curves for embalmed specimens usually had a steeper slope than those for unembalmed specimens. The slope of the load-deflection curves for vertical loading were generally steeper than those for anterior or lateral bending.

In the specimens used in our studies the age of the individual whose spine was tested seemed to have little effect on the results obtained. Thus, in vertical loading (Table II) the greatest maximum load (1350 pounds) was supported by the spine (1924) from a white man sixty years of age, the second highest load (1002 pounds) by a specimen (2176) from a white man fifty-seven years of age, and the third greatest load (978 pounds) by the spine (2257) from a white man eighty-two years of age. Even specimens from individuals of the same age showed considerable variation in load-supporting capacity. Thus, the spine from one white man sixty years of age sustained a maximum load of 1350 pounds, while the specimen (2429) from a second white man of the same age supported only a load of 862 pounds. In all these experiments the specimens consisted of similar anatomical parts and were obtained from embalmed bodies. Plotting the age of the individual against the maximum load, deflection or energy absorbed by the specimen revealed no apparent relationship between age and any of the three phenomena measured. There was also no apparent relationship between age of the individual whose spine was tested and the bending moment (Table III). The source of the specimen, that is, whether from an embalmed or an unembalmed body, had a greater influence on the results of the tests than did the age of the individual whose spine was tested.

No conclusions concerning the influence of sex or of race on the biomechanical phenomena studied are possible because all specimens were obtained from male individuals and all but two of them from white people.

SUMMARY

1. Eleven pelves and lumbar spines (eight embalmed and three unembalmed) were tested under static vertical loading; five specimens of the sacrum and the lumbar spines and five to eight thoracic vertebrae and discs (two embalmed, three unembalmed) were tested by static anterior bending; and four specimens of the sacrum and lumbar vertebrae and discs (all embalmed) were tested by static lateral bending.

2. Embalming increased the average maximum load and energy absorbed during vertical loading but decreased the magnitude of the average deflection.

3. Specimens tested by anterior bending had a greater bending moment, regardless of the condition of the specimen (embalmed or unembalmed) than those tested by lateral bending.

4. Embalmed specimens tested by lateral bending had a greater average deflection than similar specimens tested by anterior bending.

5. The greatest average amount of energy (inch pounds) was absorbed during vertical loading and the least during lateral bending. Embalming increases the energy-absorbing capacity of the pelvis and lumbar spine during vertical loading.

6. Unembalmed specimens tested by anterior bending showed the greatest average deflection.

7. Among the embalmed specimens the load increased more rapidly than the deflection in most of the specimens tested by vertical loading and in all of the specimens tested by anterior bending. In embalmed specimens tested by lateral bending the load increased more rapidly than deflection at first but later leveled off.

8. The slope of the load-deflection curve was generally steeper for specimens tested by vertical loading than for those tested by anterior or lateral bending. The slope of the curves for embalmed specimens was usually steeper than those for unembalmed ones.

9. No apparent relationship was found between the age of the individual whose spine was tested and the various biomechanical phenomena studied.

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Vertebral Osteotomy for Kyphosis, Especially in Marie-Strümpell Arthritis

A Report on Fifty Cases

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Despite adequate conservative treatment, severe deformity not infrequently develops in ankylosing spondylitis. In the early stages, correction is possible by simple orthopaedic means; but in the advanced stage, when ankylosis is complete and deformity severe, a difficult problem is encountered.

For a long time, correction of severe kyphosis seemed hopeless, for vertebral osteotomy was considered too dangerous a procedure because of possible damage to the spinal cord.

It was only about a decade ago, in 1945, that vertebral osteotomy was performed successfully for the first time. Smith-Petersen is to be given credit for this attempt. The osteotomy was not a complete one; only the neural arches of three or four vertebrae at the level of the articular processes were operated upon, and no bone was actually resected. The resulting correction was insufficient in many instances. La Chapelle, in 1946, performed the first osteotomy on the vertebral bodies incorporating a graft.

In 1947, the author reported his early cases and described a method of total osteotomy of the spine. This procedure can, if necessary, be accomplished in two stages; first, on the posterior segment, and then, on the anterior segment of the vertebral column. The technique has been little modified in subsequent use.

Law performed a number of vertebral osteotomies; his statistics will soon be reported. Urist performed two cervical osteotomies. Other authors have also reported isolated cases of vertebral osteotomy.

PATHOLOGICAL ANATOMY

Ankylosing spondylitis may be regarded as being neither constructive nor destructive, but transformative. The lesions and deformities concerned in the ankylosing process are as follows:

Anteriorly, the intervertebral discs ossify; this ossification is centripetal, starting at the periphery on the anterolateral portions of the disc, but it never extends to the center of the disc. Posteriorly, the flaval ligaments, the capsular ligaments and, less often, the interspinal ligaments ossify.

The morphological aspect of the individual intervertebral segments is altered only slightly or not at all. In elderly persons the disc may be flattened, but in young adults the ossified disc preserves its normal height and appears to undergo osseous metaplasia. Areas of destruction on a level with the disc are rare, and if such develop, they are probably associated lesions.

Pathological changes appear first in the sacro-iliac joints and the lower intervertebral discs, and tend to progress upward. Parallel with the evolution of these lesions, the vertebral column as a whole becomes distorted, assuming a typical aspect. In the majority of patients a severe kyphosis develops, often associated with a lateral deviation and starting at the thoracolumbar region. As a rule, the abdomen becomes prominent; but, in exceptional cases, it is concave, with a deep sulcus separating the xiphoid process from the pubis. In the advanced stage, the vertebral column resembles bamboo.

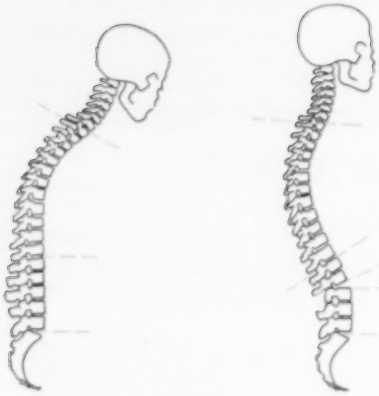

FIG. 1

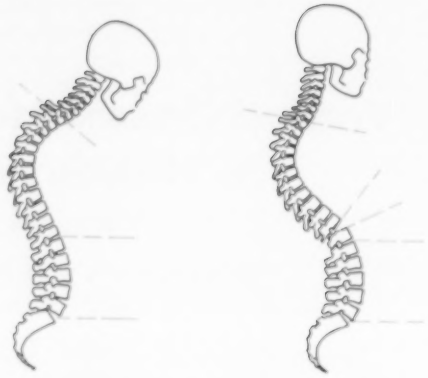

FIG. 2

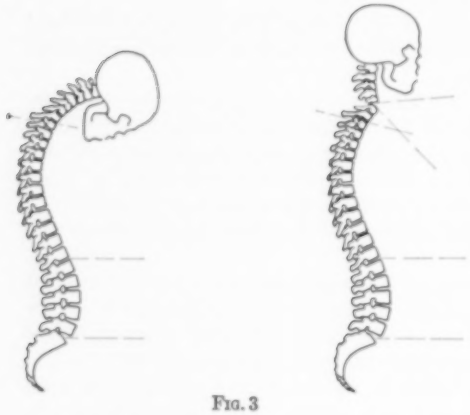

FIG. 3

Fig. 1: Vertebral osteotomy for kyphosis of low lumbar origin. Osteotomy at the level of the upper lumbar column permits tilting the entire upper vertebral segment, ensuring perfect correction.

Fig. 2: Vertebral osteotomy for kyphosis of thoracic origin. Osteotomy is performed as high as possible, but never beyond the eleventh to twelfth thoracic or the twelfth thoracic to first lumbar intervertebral disc.

Fig. 3: Vertebral osteotomy for kyphosis of cervical origin. Osteotomy is performed at about the fifth and sixth cervical interval or fourth to fifth in order to re-establish a cervical lordosis.

The kyphos itself has a variable point of origin and its mechanics are easy to understand. The initial site may be the lumbar, thoracic, thoracolumbar, or cervical region. In most instances, the kyphos originates in the lumbar region. The lordotic curve disappears and the pelvis tilts, causing the sacrum to become vertical. The thoracic and cervical columns project forward, creating the kyphos.

When the thoracic region (about the sixth and seventh thoracic vertebrae) is the site of origin, the lordotic lumbar curve is unaltered and the upper thoracic column is flexed sharply forward, becoming nearly horizontal. The examiner has the impression that he is dealing with a cervical kyphosis; actually, the lordotic cervical curve is preserved and all deformity stems from the high thoracic column.

In cases of thoracolumbar origin the lordotic curve partly disappears, and the normal thoracic curve is increased from the point of its deviation forward. At times, there is an associated lateral list of the trunk and, more rarely, a torsion of the vertebral column.

The cervical region is seldom the site of origin of the kyphos. In such exceptional cases, the normal lumbar and thoracic curves remain unaltered. It is the uppermost part of the vertebral column that is flexed sharply forward, with a concomitant torsion and lateral deviation. The cervical column and, occasionally, the upper thoracic vertebrae are involved in the deformity.

PROCEDURE

A study of the anatomical structure of the vertebral column indicates clearly

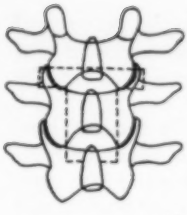

FIG. 4-A

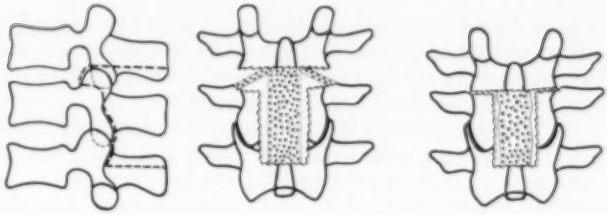

FIG. 4-B

Fig. 4-A: Schematic drawing of vertebral osteotomy, showing outline of the bone block to be resected.

Fig. 4-B: Posterior view of vertebral osteotomy, showing outline after bone resection and after correction of the kyphosis.

the levels at which osteotomy may be performed. The thoracic region is the least favorable site; little correction could be obtained because of the rigid thoracic cage at the level of the ribs and sternum. Moreover, the operation would be dangerous because the spinal cord fits closely in the narrow vertebral foramen of this region and any sudden displacement or angulation would cause serious compression of the cord. Osteotomy may be performed in either the cervical or lumbar region, although the latter is the more suitable site. At times, the operation may be carried out in the thoracolumbar region at the level of the floating ribs.

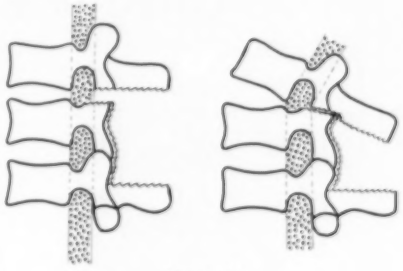

FIG. 4-C

Lateral view of vertebral osteotomy, showing outline after bone resection and after correction of the kyphosis.

From a study of the special morphology of the vertebral column in kyphosis it is clear that osteotomy of both the neural arch and anterior elements of the column may be required in order to correct deformity. It is possible by the operation described here, which can be performed in two stages, to effect complete correction. There are, on the other hand, many instances in which a one-stage operation is sufficient; ossification of the anterior structures is incomplete and the anterior longitudinal ligament ruptures spontaneously after osteotomy of the posterior elements.

The basic principles of corrective osteotomy of severe kyphosis are those of any corrective osteotomy: (1) section of the bone; (2) correction of the deformity; and (3) maintenance of the corrected position. There is, however, a certain danger in vertebral osteotomy because the epidural space lies at the center of the osseous segment to be operated on. Care must be taken to circumvent the dura mater.

Routine preoperative studies, such as blood tests, are made.

Anaesthesia is established, if possible, with endotracheal intubation. When this is not feasible, either because the head is flexed forward or because of involvement of the temporomaxillary joint, a local anaesthetic may be used. We have performed the operation under local anaesthesia on many patients. If intubation is not possible, tracheotomy may also be performed; it is especially indicated at the stage of anterior osteotomy.

The operative technique varies somewhat at the different levels of the vertebral column; therefore, lumbar or thoracolumbar and cervical osteotomy must be described separately.

LUMBAR OR THORACOLUMBAR OSTEOTOMY

First Stage: Resection of the Neural Arch

Lumbar or thoracolumbar osteotomy may be performed at any level, but the

upper lumbar region is the preferred site. The exact level may be determined from a study of the roentgenograms. If possible, a posterior space is selected that corresponds to an intervertebral disc showing little or no ossification. Thus, the second operative stage can be avoided.

The entire bone block to be resected is shaped like a T. In the mid-line, represented by the vertical branch of the T, the resection is extensive, approximating the height of two laminae. The lateral resection, represented by the horizontal branch of the T, is narrow and includes only the posterior wall of the vertebral foramen (maximum height from 0.5 to 1 centimeter). The extremities of the horizontal arm lie at the level of the intervertebral foramina.

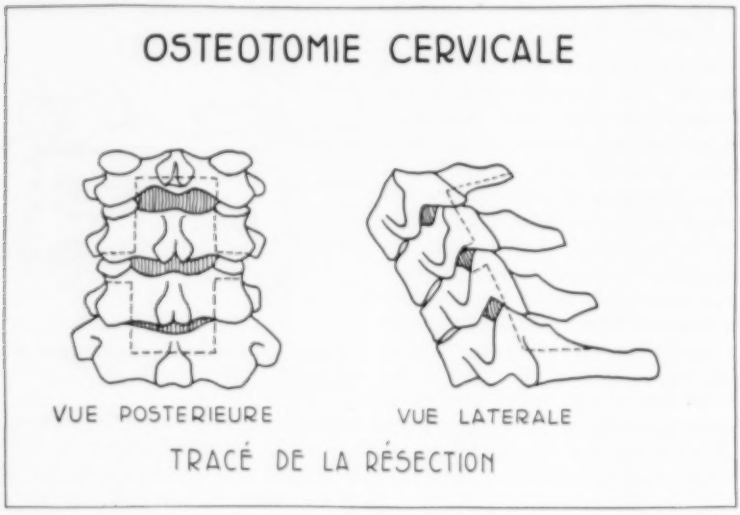

FIG. 5

Schematic drawing of cervical osteotomy, showing outline of the bone block to be resected.

Resection of the posterior arch in this manner is important; it must be borne in mind that after the operation there is often a pronounced straightening of the vertebral column which may amount to 45 or even 60 degrees. In consequence, a vertebral subluxation may take place, especially in the thoracolumbar or low thoracic region. It is always the upper segment that displaces backward. Unless provision is made by a technique such as the method of resection described here, the spinal cord will be compressed by the laminae when subluxation occurs. When the resection of the posterior arch is too narrow, there is grave danger of compression of the spinal cord by shearing.

At operation the patient lies with the pelvis and thorax supported and the abdomen free to allow diaphragmatic breathing. If respiratory excursion is limited, the operation is performed with the patient in the lateral decubitus.

A long mid-line incision is made, centered over the spinous process corresponding to the level of the osteotomy and extending over at least six vertebrae. Wide retraction of the erector spinae muscles from the vertebral grooves is then possible. The spinous processes, laminae, and articular processes are exposed by subperiosteal dissection. The muscles are retracted sufficiently to expose the bases of the transverse processes which constitute important landmarks. In fact, the posterior surface of these processes corresponds largely to the plane of the anterior face of the laminae and, therefore, to the plane of the posterior limit of the epidural space. In order to avoid injury to the dura mater, care should be taken never to advance beyond this plane.

Osteotomy is performed with an osteotome, the bone block being resected according to the predetermined plan. The osteotome is the most effective instrument because of the varying degree of hardness of the bone. In the early stages of kyphosis, still in the process of evolution, the bone is decalcified and may bleed excessively; but in the advanced stages it is avascular and as hard as ivory.

The bone is sectioned at variable angles, depending upon the segment being approached; in the mid-line, the osteotome is directed obliquely, and in the lateral portion, almost vertically. The direction of the osteotome can be varied as needed to circumvent the epidural space. As pointed out by Mathieu [2] if the osteotome is

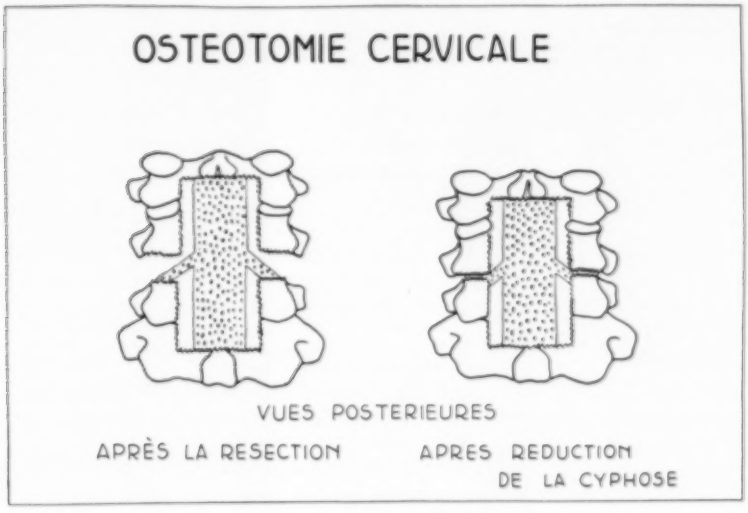

FIG. 6

Posterior view of cervical osteotomy, showing outline after bone resection and after correction of the kyphosis.

properly directed, and the thickness of the bone taken into account, there is no danger of penetrating into unsafe areas. We have not observed the slightest nerve damage during the course of the operation in any of the fifty patients on whom we operated using this technique.

At osteotomy the bone segment is always removed *in toto*, and in most cases the intervertebral foramina are exposed at this time. The nerve roots passing laterally through the foramina are checked to make certain that they are free. It is often necessary to smooth the surfaces on which osteotomy was performed with a thin rongeur or to enlarge the resection of the posterior wall of the vertebral canal. Care must be taken that no bone spicule encroaches on the dura mater.

Hemostasis is then accomplished. If bleeding is excessive at the level of the intervertebral foramina, it can be controlled by packing the area with a muscle flap or a small hemostatic sponge.

The next step is to test the mobility of the spine. As an assistant lifts the patient's shoulders, the motion at the intervertebral foraminal level is observed. The presence of motion is proof that the posterior osteotomy will be sufficient to establish correction.

The wound is closed and the patient returned to bed with great caution, where he lies on his back in his original deformed position. No attempt at correction is made at this time.

Postoperatively, the kyphotic position is maintained by pillows and cushions. These are gradually removed in the course of the next two or three days, allowing correction to take place.

In some instances, after three or four days, the anterior longitudinal liga-

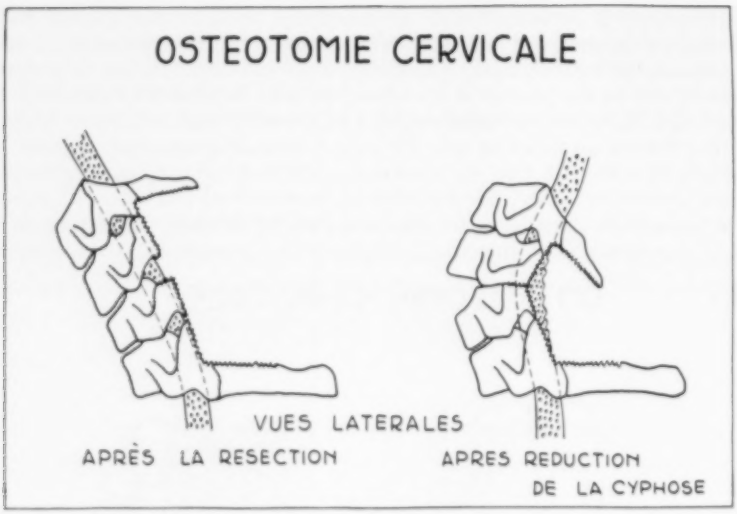

FIG. 7

Lateral view of cervical osteotomy, showing outline after bone resection and after correction of the kyphosis.

ment suddenly ruptures. Rupture can occur either at the level of an intervertebral disc, simply as the result of breaking down of ossification, or at the level of a vertebral body. In the latter case, the upper portion of the vertebra may become detached but the disc remain intact. On one occasion we observed a rupture in the middle of a vertebra. We have never encountered the slightest complication in connection with an anterior rupture, but one author has observed a rupture of the aorta. Undoubtedly the aorta in the case in question was arteriosclerotic and the anterior rupture had been violent.

During the early corrective period, the patient may experience severe pain; strong analgesics are then required. When deformity has been corrected, a plaster jacket is applied. The patient may start walking after two weeks.

If correction is not accomplished after five or six days, the anterior ossification is too dense and the second stage of the operation becomes necessary.

Second Stage: Anterior Vertebral Osteotomy

Anterior osteotomy is performed from two to three weeks after the first operative stage. The operation consists in sectioning the intervertebral disc at the level of the posterior osteotomy, thereby causing the collapse of the disc.

It is most important to know exactly which disc to approach. On the day before the operation a needle is introduced into the lumbosacral region, at the level of the posterior osteotomy, and roentgenograms are made. The insertion of the needle, which should penetrate only to the vertebral bodies, is exactly the same as for a lumbar paravertebral block. Roentgenograms show clearly the disc to be sectioned. The site of puncture is carefully marked and, at operation, a needle is again introduced and is observed to emerge beneath the psoas, exactly localizing the disc.

At operation, the patient is placed upon his right side as in approaching the left lumbar fossa. A long incision is made in the lumbo-iliac region. Because the costo-iliac space has been obliterated by the kyphosis, a passage must be made to approach the lumbar column. The ribs must be resected or osteotomy performed. The twelfth rib, and often the eleventh rib, is resected; it may be necessary to perform osteotomy on the tenth and ninth ribs in the posterior part. The muscles of the posterolateral wall of the abdomen are incised and a strong

FIG. 8-A

FIG. 8-B

Fig. 8-A: Roentgenogram of spinal column before lumbar osteotomy.
Fig. 8-B: View after osteotomy. Note that correction of deformity amounts to 60 degrees.

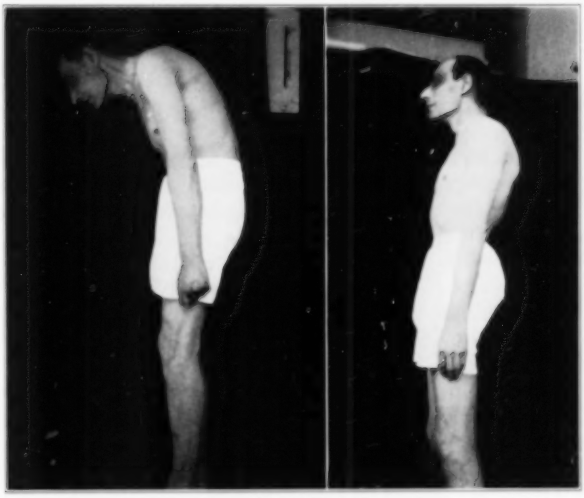

FIG. 8-C

Photographs of patient before and after lumbar osteotomy. Note the pronounced lumbar lordosis which amounts to almost an over-correction of the deformity.

retractor, similar to a rib spreader, is used to open the costo-iliac space. The abdominal mass is then separated by passing through the retroperitoneal space in front of the psoas. Two strong retractors of the Leriche type are used to retract the abdominal mass forward and to the right. By dividing the psoas it is now easy to expose the vertebral bodies and intervertebral discs.

In anterior osteotomy, at the level of the first lumbar or twelfth thoracic vertebra, it is necessary to release the insertion of the diaphragm. This is reattached at the close of the operative procedure. The danger of injury to the pleura is greater at these levels.

FIG. 9-A

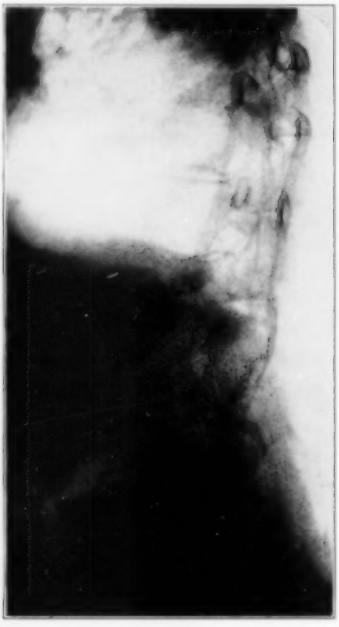

FIG. 9-B

Fig. 9-A: Roentgenogram of spinal column before thoracic osteotomy.
Fig. 9-B: View after osteotomy. Note the considerable degree of straightening of the upper segment, due to the fact that the osteotomy was at the low thoracic level. Nevertheless, the patient has no nervous disorder because the lamina of the lower segment had been removed to a sufficient extent.

In order to section the intervertebral disc, the vertebral body on either side of the disc to be ruptured is freed subperiosteally. For this purpose, a long, rather wide, curved elevator is used, with its concave surface directed toward the vertebral body so that injury to the aorta and vena cava may be avoided.

With the vertebral bodies protected by periosteal elevators, the disc is sectioned or a corner of it resected. The disc promptly ruptures.

Hemostasis is obtained. This may be difficult because of the small arterial vessels arising from the aorta. The superficial layers of the wound are closed and the patient is returned to bed.

Correction of deformity is quickly obtained within twenty-four hours. A plaster jacket is applied a few days after the operation, and the patient is able to walk at the end of four weeks. A protective jacket should be worn for a year.

CERVICAL OSTEOTOMY

Cervical osteotomy is usually performed at the level of the fifth and sixth cervical vertebrae. In principle, cervical osteotomy is similar to lumbar osteotomy, but it differs in that postoperatively a subluxation of the upper vertebral

segment may occur anteriorly as well as posteriorly after the operation. For this reason, in posterior osteotomy at the cervical level, the bone resection in the mid-line should be more extensive and include at least one vertebra above and one below the level of the osteotomy. The resected bone block should not be shaped like a T, but like a cross, with a short horizontal branch. After the operation, an apparatus with screws, similar to that designed by Urist, may be used to obtain gradual and, at the same time, safe correction of deformity. It is of the utmost importance to carry out the postoperative regimen with great care.

Three patients have had cervical osteotomy performed and in all, the posterior stage of the operation was sufficient to correct deformity.

FIG. 9-C

Photographs of patient before and after vertebral osteotomy. Plaster jacket has a chin support.

SUPPLEMENTARY OPERATIVE PROCEDURES

Bone-grafting may be necessary if there is any indication that the kyphosis may recur, or in order to promote consolidation. The spinous processes, cut in halves, may be used for the graft which is placed astride the osteotomy.

Arthroplasty of one or both hips may be indicated in conjunction with vertebral osteotomy, to obtain maximum correction of deformity.

COMPLICATIONS

The possibility of compression of the spinal cord is ever in mind in the course of the operation; actually, it seldom occurs. We observed nerve damage only in our earliest patients. It is true that the patient experiences some radicular pain for a few days after the operation, but it tends to disappear rapidly once the plaster jacket has been applied.

Nerve compression due to vertebral subluxation occurred in three patients; at the lumbar level in the first two, and at the cervical level in the third. The lumbar compression occurred eight days after the operation in one patient, and at the end of the third week in the other. Both patients were having a roentgenographic examination at the time the compression occurred, and it was easily detected from a study of the sensory and motor involvement. Operation was immediately performed and the mechanism of the compression revealed; the epi-

FIG. 10-A

FIG. 10-B

Fig. 10-A: Roentgenogram of spinal column before cervical osteotomy. Note the cervical kyphosis replacing the normal lordosis. Deformity is such that the skeleton of the face and skull is superimposed on the thoracic skeleton and the intermaxillary sternal space obliterated.

Fig. 10-B: Roentgenographic view after osteotomy. Correction of deformity, amounting to 60 degrees, is perfect and a cervical lordosis has been re-established.

dural space was squeezed between the posterior border of the upper vertebral body, which had moved backward, and the upper edge of the lamina below. Simple resection of the lamina eliminated the compression.

Spinal-cord compression at the cervical level in the third patient proved fatal. Here again, compression took place at the border of the lamina; but in this instance, the slipping of the upper vertebral body had been forward. The compression occurred suddenly, while the patient was being transported, and there was no time to attempt decompression.

A pulmonary abscess developed postoperatively in one patient, resulting in death. Anuria developed in another patient following a transfusion. Two patients died of cardiac failure, one several weeks after surgery, and the other several months postoperatively. The latter patient had shown signs of mitral insufficiency, but kyphosis had been so severe that we were requested to operate in the hope of improving the thoracic capacity. Deformity was corrected, but the cardiac deficiency was unaffected.

Deformity recurred in six patients, all of whom had failed to carry out the postoperative regimen. For example, one patient who was feeling well, discarded the protective support too soon. Obviously, kyphosis will recur if consolidation is not solid. It is important, then, that the fusion is complete, on clinical examination as well as in roentgenographic studies, before the plaster jacket or brace is discarded.

In two of our patients, marked displacement of the vertebral segment, of two or three centimeters, occurred without causing any nerve damage. The explanation lay in the fact that the technique of bone resection provided for free movement of the spinal cord backward. One of these patients, a farmer, returned to work after five months.

INDICATIONS

Although this operation is seldom done, it is applicable to many cases of vertebral kyphosis. We have performed fifty vertebral osteotomies.

Essentially, vertebral osteotomy is an operation to correct kyphosis resulting from ankylosing spondylitis. In such cases, the question arises as to the optimum time for surgical intervention; in other words, to what extent should

FIG. 10-C

Photographs of patient before and after operation. Note the flexed position, the torsion, and the lateral bending of the head before osteotomy. After operation, the patient wears a plaster jacket with a helmet.

one be influenced by the evolutional stage of the rheumatic process. This factor need not be considered at all. Operation can be undertaken during an active phase as well as at an advanced stage. Indeed, the object of vertebral osteotomy is not to restore articular mobility, but simply to correct deformity and obtain reankylosis as quickly as possible. The ankylosing process appears to be equally as rapid during an active or inactive phase.

Factors that must be considered are the age and occupational status of the patient, particularly his type of work, and the presence of associated involvement of the hips. Every case of severe kyphosis presents its special problems, which must be resolved in the best interest of the patient. Vertebral osteotomy is not an operation for elderly persons who cannot adapt themselves to a sudden alteration in statics; sixty years of age is the maximum.

Kyphosis is not too troublesome for the person who sits at his occupation. If correction is undertaken, the degree of correction desirable should be carefully weighed.

When the hips are ankylosed in flexion, it is important to determine to what degree the hip joints, and to what degree the distorted vertebral column, produce the general deformity. The more important component may be the hip involvement and, in that case, operation upon the hips alone suffices to improve the position. If, on the other hand, the hips are ankylosed in extension, an attempt should be made to restore motion by arthroplasty before correction of the flexed vertebral column is undertaken.

ANALYSIS AND RESULTS

Our experience includes fifty vertebral osteotomies; one was performed for congenital kyphosis, one for traumatic kyphosis, and forty-eight were performed for ankylosing spondylitis. The majority of the patients were between the ages of thirty-five and fifty. In only ten patients, all of whom had had ankylosing

spondylitis, were two operative stages necessary to obtain correction. We performed secondary bone-grafting in nine of the fifty patients, using preserved homogeneous bone.

The patient with congenital kyphosis was a girl, eighteen years old, who had a severe deformity with a pronounced lumbar gibbosity and a deviation of the vertebral column to the right. In roentgenograms, the sacrolumbar and low thoracic regions were revealed as a bone block, and the intervertebral discs could not be distinguished. This osseous block was flexed at a right angle near the thoracolumbar junction.

Osteotomy was performed posteriorly in one stage. A large resection of the neural arch was first made. Then, because the vertebral bodies projected posteriorly owing to the marked angulation, it was possible with an osteotome to section the bone block of the vertebral bodies in front, and break open the spinal column. The result is excellent.

The patient who had the traumatic kyphosis was a man fifty years old. There was no significant ankylosis in this patient, and correction was easily obtained by a posterior osteotomy.

The group of forty-eight patients who had had ankylosing spondylitis included forty-four men and four women. The level of the osteotomy was as follows: the lumbar level in thirty patients; the thoracolumbar (fifth thoracic to first lumbar) in seven patients; the low thoracic in seven (eleventh to twelfth thoracic in six, and ninth to tenth thoracic in one); the upper thoracic (third, fourth, and fifth thoracic) in one; and the cervical in three (fourth to fifth cervical in two, and sixth to seventh in one patient). In one patient it was possible to section the vertebral-body segment by the posterior approach, as in the patient with congenital kyphosis.

Deformity recurred in six patients, two of whom underwent a second operation. All six patients had not been diligent in following postoperative instructions.

There was a recurrence of a varying degree of deformity when correction had not been sufficient, and the patients still had a static defect. In such cases, the general effect of the forces is forward, creating a momentum of flexion which is conducive to reproduction of deformity. On the other hand, when deformity is well corrected, and satisfactory spinal balance restored, the danger of secondary deformity is negligible.

Arthroplasty of the hip was performed in six patients. In two, the mobilization was carried out prior to the vertebral osteotomy, on one hip in one patient, and on both hips in the other. The four arthroplasties performed subsequent to the osteotomy were bilateral in two patients, and unilateral in the other two.

SUMMARY

A technique of vertebral osteotomy for the correction of severe kyphosis is described which, if necessary, can be performed in two stages; on the posterior segment and the anterior segment of the spinal column, respectively. The levels suitable for osteotomy are discussed.

Indication for the procedure is based upon the age and occupational status of the patient and upon the presence of concomitant lesions, especially at the hips.

The results, in fifty patients on whom vertebral osteotomy was performed according to this technique, have been favorable. In the majority, the deformity had been so severe that it caused considerable functional disturbance. After osteotomy, general health was much improved and the visceral capacity increased. The evolution of the arthritic process ceased in nearly all cases. The emotional status of the patients was improved; a feeling of inferiority was eliminated because the patient could walk without difficulty.

(References are on page 320)

Spondylolysis

Its Anatomy and Mechanism of Development

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The following paper presents the results of an analysis of a number of cases of spondylolysis which were observed in human skeletons in the course of a study of changes in the vertebral column due to age. In some of these skeletons it was possible to reconstruct the relationship between the different parts involved and to reach certain conclusions regarding the etiology and pathogenesis of spondylolysis. A comparison of normal, non-spondylolytic vertebral columns with spondylolytic ones led to the recognition of anatomical characteristics which seem to be important in the development of the condition. Furthermore, skeletons were found with incomplete spondylolytic lesions of the neural arch; these were studied in an attempt to detect the causative agents of the lesions and to determine the factors which may have interrupted the progress of the lesions before total separation of the neural arch had occurred.

The most important anatomicopathological complication of spondylolysis is spondylolisthesis [67], that is, a sliding forward of the separated body of the affected vertebra together with that part of the vertebral column above it. As the one process conditions the presence of the other, the subject of spondylolysis is frequently dealt with in the literature under the heading of spondylolisthesis. However, there are descriptions [2,29,41,51,63] of spondylolisthesis without spondylolysis (pseudospondylolisthesis), that is, a sliding forward of part of the vertebral column without separation of a neural arch. The etiology and pathogenesis of this condition is different from that of classic spondylolisthesis and will not be considered here.

MATERIALS AND METHODS

Nineteen instances of spondylolysis were found in a total of 450 skeletons examined; 350 of these skeletons were from the Todd Collection in the Department of Anatomy of Western Reserve University, Cleveland, Ohio, twenty-five were from the Department of Anthropology of the Museum of Natural History, New York, and seventy-five were from our department and other sources.

In the 350 skeletons of the Todd Collection there were approximately two white males to each white female, Negro male, or Negro female. Approximately half of the total of 450 skeletons were of individuals less than fifty years of age. The selection of these skeletons was made with a view to arriving at these proportions for the purposes of the age-change study, but the choice of material was non-selective with regard to the presence of spondylolysis.

The age, sex, and race of the skeletons of the Todd Collection and Museum of Natural History were ascertained from the collection archives, bearing in mind the published reservations [92,93]. In the remaining material, these data were obtained from an examination of the bones and are therefore only approximate. The age, sex, and race particulars of the nineteen instances of spondylolysis are shown in Table I. In each a detailed study was made of the affected vertebra and the vertebrae immediately above and below it. The vertebrae were examined in-

* Formerly Hilel Notkovich.

TABLE I

AGE, SEX, AND RACE DISTRIBUTION OF THE NINETEEN CASES OF SPONDYLOLYSIS
(Number of Skeletons Examined: 450; Incidence: 4.22 Per cent)

Sex and Race	Age (*Years*)								
	30—40	40—50	50—60	60—70	70—80	80—90	90—100	Over 100	Total
Male									
White	1	2	2	3	2	1			11
Negro	1					1		1	3
Mongolian (Japanese)			1						1
Female									
White			1	1			1		3
Mongolian (Eskimo)	1								1
Total	3	2	4	4	2	2	1	1	19

TABLE II

LOCALIZATION AND DISTRIBUTION OF THE CLEFTS IN THE NINETEEN CASES OF SPONDYLOLYSIS
(Twenty-three Vertebrae Affected)

Type	Vertebra Affected							No. of Vertebrae Affected	No. of Cases
	1L	2L	3L	4L	5L	6L	S		
Typical (16 cases)									
Univertebral (15 cases)									
Bilateral				1	11	1	1	14	14
Unilateral					1R*			1	1
Trivertebral (1 case)									
Bilateral			1	1	1			3	1
Atypical (2 cases)									
Univertebral (2 cases)									
Unilateral	1R	1R						2	2
Mixed: typical and atypical									
Trivertebral (1 case)									
Typical									
Bilateral					1			1	
Atypical									
Unilateral			1R					1	
Bilateral		1						1	1
							Totals	23	19
No. of times each vertebra affected	1	2	2	2	14	1	1		

*R = Spondylolysis localized in right isthmus.

dividually and also after being articulated. Attention was paid to such bone impressions and articular facets as might allow reconstruction and interpretation of the anatomical relationship that existed during life.

Many non-spondylolytic vertebral columns were also examined in detail and compared with the spondylolytic specimens. Skeletons with incomplete spondylolytic lesions were studied in the same way.

In addition, we studied roentgenograms of a number of patients with spondylolysis who were seen at the Hadassah-University Hospital.

We observed that in the nineteen cases of spondylolysis it was possible to distinguish two types: typical and atypical.

TYPICAL SPONDYLOLYSIS

Typical spondylolysis was found in sixteen skeletons. In most cases, the dis-

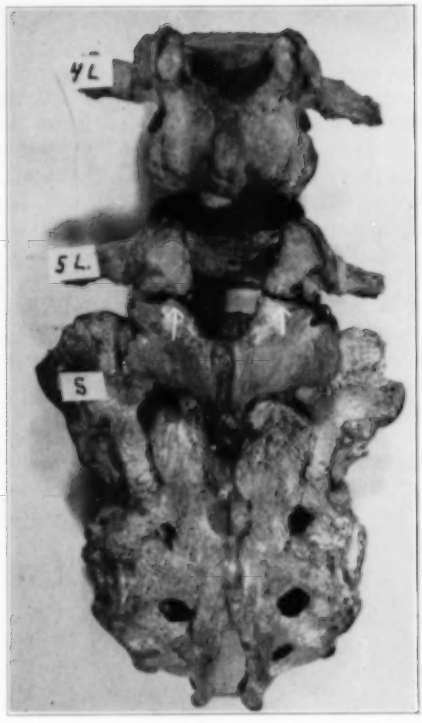

FIG. 1-A

FIG. 1-B

Figs. 1-A through 1-C: Typical spondylolysis of the fifth lumbar vertebra.

Fig. 1-A: Disarticulated fourth lumbar vertebra (4L), articulated fifth lumbar vertebra (5L), and sacrum (S). The fifth lumbar shows a separate neural arch and bone impressions adjacent to the cleft on both sides (arrows). The articular processes of the sacrum are directly related to the clefts.

Fig. 1-B: Articulated fourth lumbar vertebra, fifth lumbar vertebra, and sacrum; right lateral view. The cleft of the right isthmus is clearly seen between the inferior articular process of the fourth lumbar (4L arrow) and articular process of the sacrum (S arrow). The cleft isthmus (i.i.) is thinner than normal.

Fig. 1-C: Higher magnification of Fig. 1-B. (The skeleton used in this case was found in 1955 along with others in a cave in Wadi Hadra, near the Dead Sea. The archeological evidence points to these being the remains of Jewish refugees of the period of the revolt of Bar Kochba against the Romans, about 73 A.D. The skeletal material was obtained for study by courtesy of the Department of Antiquities of the Government of Israel.)

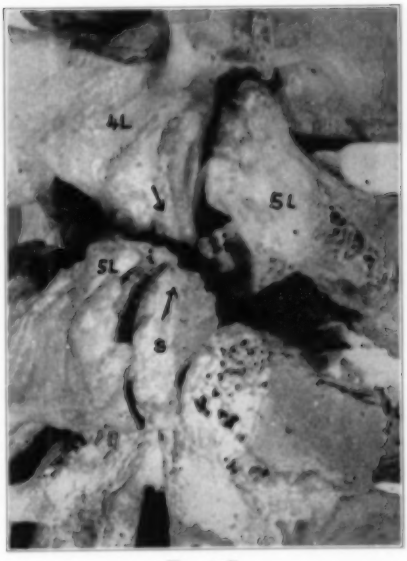

FIG. 1-C

ease was in the lower lumbar vertebrae, most frequently the fifth, and was usually bilateral; that is, the neural arch was separated on each side from the rest of the vertebra. A description of the condition, as seen in the fifth lumbar ver-

tebra, points out the characteristics seen in other vertebrae with lesions of the same type.

The neural arch of the vertebra was separated on each side from the rest of the vertebra by a cleft or hiatus through the isthmus or pars interarticularis. The direction of the cleft was transverse, or oblique, following the planes of the adjacent articular processes of the vertebrae immediately above and below the affected vertebra. The surfaces of the cleft were irregular and sometimes showed bone spicules. In the immediate vicinity of the cleft, both on the lamina and on the isthmus, the bone surface was very rough and irregular (Fig. 1-A). These bone changes were more marked in the dorsosuperior than in the ventro-inferior aspect of the lamina and isthmus. Among them one could see a depression or pit on the dorsal surface of the separated neural arch adjoining the cleft. This depression continued across the cleft with the articular surface of the superior articular process of the same vertebra, and was often deeper on one side of the vertebra than on the other. When the separated parts of the affected vertebra were put together and articulated with the fourth lumbar vertebra and the sacrum, it was noted that the tip of the inferior articular process of the fourth lumbar lay exactly on the superior aspect of the cleft or partly penetrated it (Figs. 1-A through 1-C and 9). Furthermore, this articular process occupied the depression or pit on the dorsal aspect of the lamina just described and was in contact with the bone irregularities within the pit.

On its inferior aspect, the position of the cleft corresponded with that of the articular process of the sacrum (Figs. 1-A through 1-C, 3-A through 3-C, and 9). The affected vertebra, in fact, rested by its cleft isthmuses on the sacral articular processes. In some instances, the inferior articular process of the fourth lumbar vertebra and the articular process of the sacrum penetrated the cleft so deeply that the two processes made contact within it. In these cases, reciprocally corresponding bone impressions were seen on the two articular processes at the site of contact (Figs. 3-A through 3-C).

The same relationship, between the inferior articular processes of the fourth lumbar vertebra, the articular processes of the sacrum, and the cleft isthmuses of the fifth lumbar vertebra, was observed in roentgenograms of the patients with spondylolysis (Fig. 5).

Thus, in the cases of typical spondylolysis, the cleft of the isthmus was situated clearly between the downward projecting inferior articular process of the vertebra above, and the upward projecting superior articular process of the vertebra below. It was also noted that both on its superior and inferior surface, the isthmus shelved gradually toward the cleft (Figs. 1-A through 1-C and 9); the isthmus as a whole was thus usually thinner than that of non-affected lumbar vertebrae in the same skeleton, or of the corresponding vertebra in non-spondylolytic skeletons.

In all the cases of typical spondylolysis the proportions of the vertebral bodies, their spines, transverse and articular processes and the relationship between them were such that when the vertebrae were articulated and manipulated the movement of the articular processes toward the cleft isthmus was not hindered (Fig. 8). Frequently, the tubercles of the middle sacral crest (spinous processes of the sacrum) were atrophic or absent (spina bifida). Spina bifida was present in seven of the sixteen cases, four being in the sacrum and three in the fifth lumbar vertebra. When these proportions and relationships are compared with those existing in normal (non-spondylolytic) skeletons (Figs. 6 and 7), it is seen that generally, in the latter, the inferior articular processes of the fourth lumbar vertebra and the articular processes of the sacrum are unable to reach and compress the isthmuses of the fifth lumbar vertebra because (1) both these processes may be relatively short; (2) the vertebral bodies may be relatively tall and their discal surfaces impinge on each other; (3) relatively large spinous processes of the fourth and fifth lumbar vertebrae may make contact, and similarly

FIG. 2-A

FIG. 2-B

Figs. 2-A through 2-D: Prespondylolysis.

Fig. 2-A: Isolated fifth lumbar vertebra (L5); posterosuperior aspect. The laminae and isthmuses show bone depressions adjacent to the superior articular processes particularly on the right side (arrow).

Fig. 2-B: Inferior aspect of the same vertebra (L5). The right isthmus shows a deep oblique bone depression (arrow) just in front of the inferior articular process.

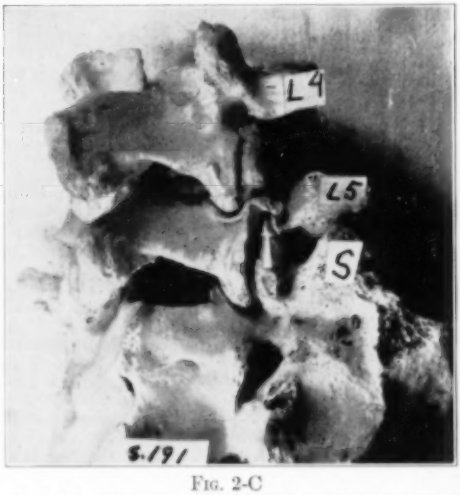

FIG. 2-C

FIG. 2-D

Fig. 2-C: The same fifth lumbar vertebra (L5) articulated with the fourth lumbar vertebra (L4) and the sacrum (S); right oblique view. The inferior articular process of the fourth lumbar vertebra (L4, arrow) and the articular process of the sacrum (S, arrow) occupying, respectively, the depressions observed on the superior and inferior aspects of the isthmus of the fifth lumbar vertebra (L5). This isthmus of the fifth lumbar is reduced to a thin bridge of bone joining the neural arch to the rest of the vertebra. The right transverse process of the fourth lumbar vertebra is in contact with the lateral part of the right superior articular process of the fifth lumbar, and the right transverse process of the fifth lumbar touches the right ala of the sacrum.

Fig. 2-D: Higher magnification of Fig. 2-C.

the spinous process of the fifth lumbar vertebra may rest on a relatively large sacral spinous tubercle; (4) relatively large transverse processes of the fifth lumbar vertebra may rest on the alae of the sacrum (sacralization of the fifth lumbar vertebra); and (5) the roots of the transverse processes of the fourth lumbar vertebra may rest on well developed laterally projecting upper parts of the superior articular processes of the fifth lumbar vertebra.

Different normal skeletons present a varying number and varying degree of the characteristics mentioned; the features actually preventing compression in particular sets of articulated vertebrae vary from case to case.

Prespondylolysis

The term prespondylolysis is used to describe cases that were found in the

FIG. 3-A

FIG. 3-B

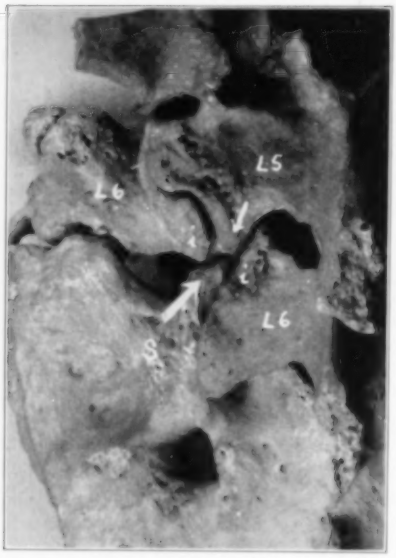

FIG. 3-C

Figs. 3-A through 3-C: Typical spondylolysis of a sixth lumbar vertebra.

Fig. 3-A: Sixth lumbar vertebra (partially sacralized on the left) articulated with the sacrum; the sixth lumbar vertebra (L6) presents cleft isthmuses. The articular processes of the sacrum (arrows) project into the clefts.

Fig. 3-B: Articulated fifth lumbar vertebra (L5), sixth lumbar (L6), and sacrum (S). The inferior articular processes of the fifth lumbar and the articular processes of the sacrum (arrows) project into the cleft isthmuses of the sixth lumbar (i.i.). On the left side, the penetration is deeper; the inferior articular process of the fifth lumbar (L5, arrow) descends in the cleft till it reaches the articular process of the sacrum (S, arrow) and articulates with it by means of corresponding bone facets.

Fig. 3-C: Higher magnification of Fig. 3-B.

intermediate zone between spondylolytic and normal vertebral columns. In these instances, contact between the isthmus and the articular process above and below did take place. Furthermore, bone depressions of varying size and depth, directly related anatomically to the impinging articular processes of the adjoining vertebrae, were found on the isthmus and lamina, but no separation of the neural arch was present.

A typical example of this anomaly can be seen in Figures 2-A through 2-D. On each side, the fifth lumbar vertebra showed a deep depression on the superior and inferior aspect of the isthmus, with only a thin plate of bone—the remains of the isthmus—intervening (Figs. 2-A and 2-B). When this vertebra was articulated with the adjoining vertebrae, the depressions on the isthmus were found to be occupied by the tips of the inferior articular processes of the fourth lumbar vertebra and the tips of the articular processes of the sacrum (Figs. 2-C and 2-D). The inferior borders of the transverse processes of the fourth

FIG. 4-A

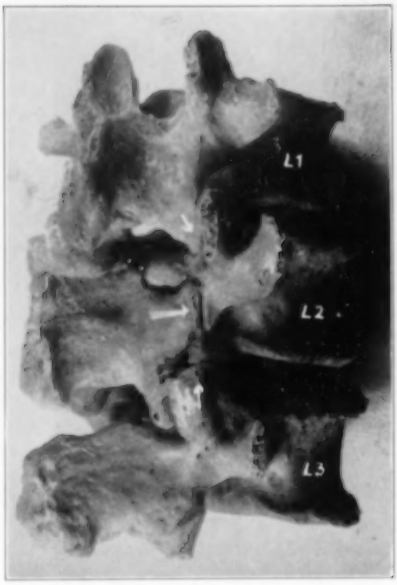

FIG. 4-B

Figs. 4-A and 4-B: Atypical spondylolysis.
Fig. 4-A: Isolated second lumbar vertebra showing a unilateral cleft on the right side. The cleft (arrows) consists of an inferolateral part running vertically through the isthmus, and a superomedial part running horizontally through the lamina. The former has smooth surfaces whereas the latter has irregular borders. No bone depression or erosion is present as in cases of typical spondylolysis.
Fig. 4-B: The articulated first, second, and third lumbar vertebrae. The cleft (L2, arrow) is not directly related to the inferior articular process of the first lumbar vertebra above (L1, arrow) or to the superior articular process of the third lumbar vertebra below (L3, arrow).

lumbar vertebra rested on the lateral expanded parts of the tips of the superior articular processes of the fifth lumbar vertebra.

Typical Spondylolysis in Special Cases

Spondylolysis in vertebral columns showing anatomical variations or anomalies was noted in four skeletons. In Case 1, spondylolysis was present in the first sacral vertebra which was lumbarized, occupying the position of a normal fifth lumbar vertebra. Furthermore, it showed spina bifida. The relationship between its cleft isthmuses and the articular processes of the fifth lumbar vertebra above and the second sacral vertebra below were like those already described for an affected fifth lumbar vertebra lying between the fourth lumbar vertebra and a normal sacrum.

In Case 2, the affected fourth lumbar vertebra occupied the position and had the relationship of a normal fifth lumbar vertebra. The relationship of the cleft isthmuses to the articular processes above and below it were as in other typical cases previously described.

In Case 3, six lumbar vertebrae were present and the sixth vertebra was the one affected. Its position and relationship were those of a normal fifth lumbar vertebra. The relationship of the cleft isthmuses with the articular processes above and below it were as in all typical cases seen. On the left side, the inferior articular process of the fifth lumbar vertebra descended into the cleft and made contact with the articular process of the sacrum (Figs. 3-B and 3-C).

In Case 4, lumbar scoliosis with the concavity to the right was present; on the left side sacralization of the transverse process of the fifth lumbar vertebra was present. This vertebra—which also showed spina bifida—had a cleft right isthmus. The cleft bore the relationship to the articular process above it and to that below it as described in all cases of typical spondylolysis. The body of the vertebra was shorter in its right than in its left half; the right half also showed necrosis on its upper surface and numerous osteophytes at its peripheral margin.

In all four cases bone depressions on the lamina and isthmus, adjacent to the clefts, were present as in the other typical cases (Fig. 3-A). In Case 4, where

FIG. 5-A

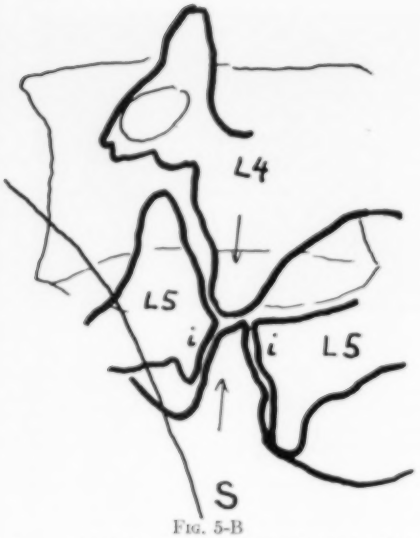

FIG. 5-B

Fig. 5-A: Left oblique roentgenogram of a spine with bilateral spondylolysis of the fifth lumbar vertebra (L5).

Fig. 5-B: The articular process of the sacrum (S, arrow) projects upward and penetrates deeply into the cleft, meeting the downward projecting inferior articular process of the fourth lumbar vertebra (L4, arrow).

the lesion was unilateral, the depressions were present only on the affected side. On the other side the isthmus was normal in appearance and did not make contact with articular processes of the adjoining vertebrae.

Multiple vertebrae were affected in one skeleton—Case 5. In this skeleton—that of a female Eskimo—the third, fourth, and fifth lumbar vertebrae were all bilaterally affected. The separated arch of the fourth lumbar vertebra was present in the collection but the arches of the third and fifth were missing. When the vertebrae were articulated, the relationship between the spondylolytic clefts and the articular processes available for articulation were as in other cases of typical spondylolysis.

ATYPICAL SPONDYLOLYSIS

Two cases of spondylolysis were found in which the clefts were not related to the articular processes of the adjoining vertebrae. They are referred to as atypical spondylolysis. In one of them the first lumbar vertebra was affected and in the other, the second lumbar; in both instances, the cleft was on the right side only and its appearance similar (Figs. 4-A and 4-B). It proceeded upward vertically from the lower border of the isthmus for about two thirds of the way through the latter; it then turned medially through the entire width of the superior part of the lamina. The cleft may thus be said to have had an inferolateral and a superomedial part; the former—located in the isthmus—was smooth, with the opposing faces resembling articular surfaces; the latter—passing through the lamina—was more irregular. No bone depressions or pits, such as were found in cases of typical spondylolysis, were seen on the lamina or any other part of the neural arch. Neither the inferior articular process of the vertebra above nor the superior articular process of the vertebra below bore a direct relationship to the cleft (Fig. 4-B).

Typical and atypical spondylolysis was present in only one skeleton. The fifth lumbar vertebra had bilateral clefts with all the characteristics and relationships of the cases of typical spondylolysis described. The second lumbar vertebra had bilateral atypical clefts and the third lumbar vertebra a unilateral, atypical cleft on the right side.

DISCUSSION AND CONCLUSIONS

From the present work no decision can be arrived at regarding the etiology of atypical spondylolysis. The clefts in these skeletons seem to be simple fractures which failed to heal for some undetermined reason. The striking similarity between the pattern of the clefts in the cases of atypical spondylolysis presented here and the neural arch defects in the first and second lumbar vertebrae of the Eskimos described by Stewart [88] renders it likely that there is some common underlying mechanism. Fractures of the vertebral column occur most frequently in the twelfth thoracic and first lumbar vertebrae [15,20,40,61,62]; it is possible that there is some connection between this fact and the finding of atypical spondylolysis in the upper lumbar vertebrae.

With regard to typical spondylolysis, the position appears to be clearer; it is possible from the material described here to deduce the etiology and pathogenesis of the condition. The thinning of the isthmus, the bone depressions or pits on the laminae, and the irregularities near the cleft, all intimately related to the articular processes of the vertebrae immediately above and below, can hardly have been produced other than by means of pressure exerted by these selfsame articular processes. This and the very clear and constant relationship of the cleft to these articular processes (Figs. 1-A through 1-C, 3-A through 3-C, 5-A, 5-B, and 9) make it likely that these processes act as etiological mechanical agents in the production of spondylolysis.

This thesis is supported by the cases referred to as examples of prespondylolysis, where depressions were present on the superior and inferior aspects of the isthmus but where no cleft had developed (Figs. 2-A through 2-D). Prespondylolysis is not to be confused with prespondylolisthesis, a term introduced by Whitman and used as a synonym for spondylolysis. In articulated vertebral columns, these depressions were occupied by the articular processes of the adjoining vertebrae (Figs. 2-C and 2-D) and there seems to be little doubt that the pressure exerted during life by these processes produced the depressions. The combined pressure of the inferior articular process of the vertebra above and of the superior articular process of the vertebra below may be described as a pincers effect (Fig. 8). Had this effect been continued, the depression would gradually have become deeper and finally a complete cleft would have developed, resulting in a case of typical spondylolysis (Fig. 9). It may well be that in some cases the final breakthrough of the thinned, weakened isthmus occurs suddenly as the result, for example, of a jump or a fall; descriptions of acute, traumatic cases of spondylolysis are found in the literature [69,70]. Some authors [9,54,56,57,66] have recorded a history of trauma preceding the onset of symptoms in a large proportion of cases of spondylolysis and spondylolisthesis.

The depressions in the neural arch are in all likelihood the result of traumatic mechanical erosion; between the two impinging articular processes a zone of osteoporosis and osteolysis probably develops, possibly as a result of local circulatory deficiency, and ultimately the bone is replaced by fibrous tissue of that particular type found in spondylolytic clefts [2,9,65]. Such a process has been described by Brandt [11] as occurring in "creeping fractures". These fractures, which he described in the metatarsals and other bones, develop insidiously by a summation of repeated mechanical insults. Henschel [34] detailed the different stages of this process in the development of these "exhaustion fractures".

A preceding bone abnormality or defect of the isthmus need not be necessarily present for the development of spondylolysis; it would seem to be demanding too much from coincidence for weakness of the neural arch, due to an ossification defect or some other cause, to be always present precisely in that part of the isthmus of an affected vertebra against which the adjoining articular processes impinge. However, if there should be some local weakness of the isthmus as a result of caries [44], defective ossification with cystlike spaces [14], the presence of large sinus-

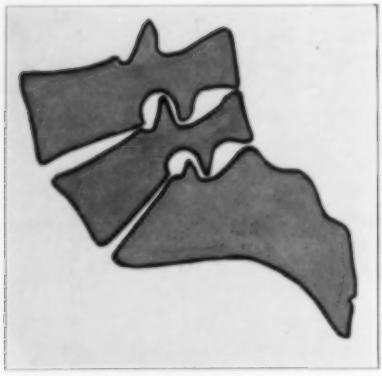

FIG. 6

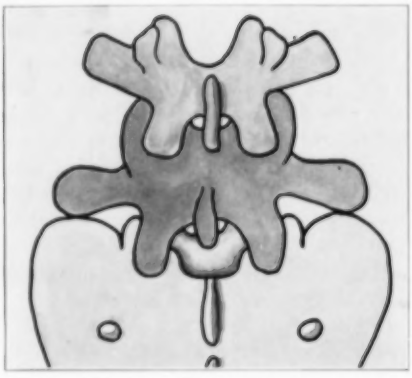

FIG. 7

Fig. 6: Schematic, lateral-view drawing of a non-spondylolytic spine. In such spines, the contact between the vertebral bodies and spines or the relatively hypertrophic superior or inferior articular processes of the fifth lumbar vertebra does not allow the compression of the isthmus of the fifth lumbar by the articular processes of the fourth lumbar and sacrum. The development of spondylolysis seems to be impossible in such instances. The drawing is made intentionally with maximum thinning of the intervertebral discs; thicker discs will further diminish the possibility of compression of the isthmus by the articular processes.

Fig. 7: Schematic, posterior-view drawing of a non-spondylolytic spine. The contact between the lateral parts of the well developed superior articular processes of the fifth lumbar vertebra with the root of the transverse process of the fourth lumbar prevents the descent of the inferior articular process of the fourth lumbar toward the isthmus of the fifth lumbar vertebra. The contact between hypertrophic transverse processes of the fifth lumbar with the alae of the sacrum, or articulation between these processes and the alae (sacralization), will not allow the articular processes of the sacrum to reach the isthmuses of the fifth lumbar vertebra.

oidal blood vessels [6,38,52,96], osteochondritis secondary to bone infarct resulting from injury during or after birth [10,58], or inflammatory processes following trauma [35], then obviously the traumatic action of the articular processes against the isthmus would be facilitated.

If this theory of the production of spondylolysis by pressure exerted on previously normal isthmuses is correct, it may well be asked why it is that spondylolysis, or at any rate prespondylolysis, does not develop in all vertebral columns and why, when it does develop, it occurs most often in the fifth lumbar vertebra.

The answer to the first question is to be found in differences observed between spondylolytic and non-spondylolytic vertebral columns; in the size, proportions, and form of the vertebral bodies, their spines, transverse and articular processes, and the relationship between them. In the spondylolytic cases these proportions and relationships were such that the articular processes above and below the affected vertebra were free to reach and compress the isthmus (Figs. 8 and 9); in normal, non-spondylolytic spines, however, these articular processes were not free to reach the isthmus and development of spondylolysis was not possible (Figs. 6 and 7). The anatomical differences observed between the vertebrae in spondylolytic and normal spines seem to be fundamental in conditioning the development of spondylolysis. They may be referred to as predisposing or conditioning anatomical factors. These have been listed in the description of the non-spondylolytic skeletons.

It is fully realized that the absence of intervertebral discs from the skeletal material of the present study needs to be taken into account. It is clear that thick, healthy discs will have a separating effect on the vertebral bodies and will thus tend to hinder the impingement of the adjoining articular processes on the isthmus. Thin intervertebral discs will have an opposite effect and will facilitate the development of spondylolysis, especially when the bone factors are such as to permit the impingement of the adjoining articular processes on the isthmus. Thus, the thickness of the intervertebral discs may be considered to be one of the condition-

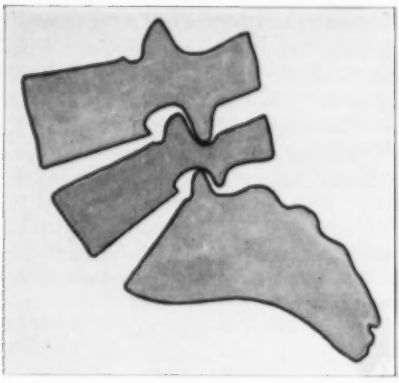

FIG. 8

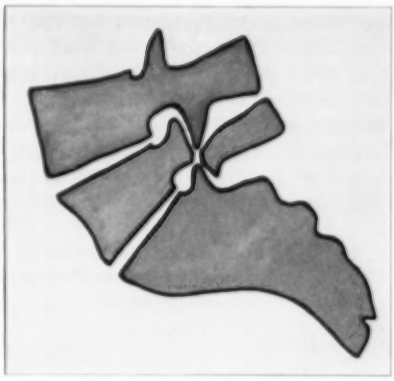

FIG. 9

Fig. 8: Schematic drawing of a type of vertebral column which is anatomically predisposed to the development of spondylolysis. The isthmus of the fifth lumbar vertebra rests below on the upward projecting articular process of the sacrum; the inferior articular process of the fourth lumbar vertebra exerts pressure from above. These two articular processes thus compress the isthmus in a pincers grasp. The vertebral bodies, spinous processes, and other vertebral processes do not hinder this compressing mechanism.

Fig. 9: Schematic drawing of a spine with typical spondylolysis. This spine, the same type as in Fig. 8, shows the cleft of the spondylolysis. The articular processes of the fourth lumbar and sacrum are directly related to the cleft and penetrate it somewhat.

ing anatomical factors. This aspect is referred to in discussing the influence of age.

In some cases the conditioning anatomical factors may allow only a limited degree of compression, so that prespondylolysis (Figs. 2-A through 2-D) develops with bone depressions, but no cleft in the isthmus; thereafter, these factors hinder further penetration of the articular processes. This would seem to have been the case in the instance described of prespondylolysis in which the lateral, expanded parts of the tips of the superior articular processes of the fifth lumbar vertebra were in contact with the inferior borders of the transverse processes of the fourth lumbar vertebra.

The concept of conditioning or predisposing anatomical factors is strengthened by the characteristics noted in Case 4. Here, the fifth lumbar vertebra in a case of scoliosis, with the concavity to the right, had a cleft right isthmus. The body of this vertebra showed clear signs of compression in its right half and the shorter height of this half of the vertebra facilitated the descent of the fourth lumbar vertebra on this side. Signs of compression of the isthmus and lamina were present on the right side only. The affected vertebra also showed spina bifida.

The finding of anatomical variations in the spondylolytic spine is significant. Thus, Roche and Rowe [72] in their large series of cases found the incidence of spina bifida of the fifth lumbar vertebra to be four and a half times as frequent as is normally expected (using Willis' findings [96] as a basis); the incidence of spina bifida of the sacrum was twice as frequent as normally expected (as established by Trotter [94]). On the other hand, articulation of the transverse process of the fifth lumbar vertebra with the sacrum was found only one-third or one-quarter as frequently as normally expected. Similar observations were made by Friberg [24] who found spina bifida in 28.6 per cent of the 280 cases of spondylolysis he studied; only one case of spondylolysis was associated with total sacralization. Bosworth and his associates [9], in their series of 115 cases of spondylolysis, found thirty with coincidental spina bifida and forty-five with underdevelopment of the arch of the fifth lumbar vertebra. In the seventeen cases of typical spondylolysis described in our study, seven instances of spina bifida were found; four in the sacrum and three in the fifth lumbar vertebra. This is a much higher incidence than normally expected. The absence of underdevelopment of spinous processes

may be regarded as a factor favoring the descent of the vertebrae and the production of spondylolysis. On the other hand, sacralization may be regarded as a condition which prevents the development of spondylolysis. Lerner and Gazin's [49], and later, Stewart's [89] observations that the bodies of vertebrae with spondylolysis are proportionally lower in their posterior part are significant and agree with the findings in the present investigation; such lowering may be considered a factor favoring the descent of the posterior arch and compression of the isthmuses.

TABLE III

INCIDENCE OF SPONDYLOLYSIS (NON-SELECTED CASES)

Source	No. of Persons Examined	Percentage with Spondylolysis
Rhodes and Colangelo[66]	1,000	2.1
Bailey[4]	2,080	4.4
Stewart[86]	1,049	4.6
Roche and Rowe[72]	4,200	4.2
Runge[74]	4,654	2.08

TABLE IV

INCIDENCE OF SPONDYLOLYSIS IN RELATION TO RACE

Source	No. of Specimens Examined	Percentage Showing Spondylolysis: Mongolian Eskimos	Mongolian Lapps	Mongolian Japanese	American Aborigines	White	Negro American	Negro Bantu
Stewart[88]	786	26.3						
Schreiner[79]	296		12.8					
Hasebe[32]	125			5.6				
Taguchi[90]	97			10.3				
Adachi[1]	67			10.8				
Congdon[16]	200				5			
Roche and Rowe[72]	2,300					5.8		
Roche and Rowe[72]	1,900						2.4	
Shore[83]	82							6.9

TABLE V

SEX INCIDENCE OF SPONDYLOLYSIS IN DIFFERENT RACES

	No. of Skeletons Examined	Percentage Showing Spondylolysis: Eskimo (*Male*)	Eskimo (*Female*)	White (*Male*)	White (*Female*)	Negro (*Male*)	Negro (*Female*)
Stewart[88]	786	32.6	22.2				
Roche and Rowe[72]	2,300			6.4	2.3		
Roche and Rowe[72]	1,900					2.8	1.1

Why does spondylolysis develop, in the great majority of cases, in the fifth lumbar vertebra? It would seem that this comes about because of the special position and relationship of this vertebra in the lumbar curvature of the vertebral column and the position of the sacrum. The fifth lumbar vertebra normally occupies an intermediately oblique position between the obliquely lying sacrum and the almost vertically situated fourth lumbar vertebra (Figs. 6 and 8). The compressive forces of the spinal column which, in higher regions, are transmitted mainly through the vertebral bodies and intervertebral discs will here be transmitted in greater part through the neural arches [13,28]. In anatomically predisposed skeletons,

these compressive forces will pass directly from the inferior articular processes of the fourth lumbar vertebra to the isthmuses of the fifth lumbar vertebra and from there to the articular processes of the sacrum (Fig. 8). The isthmuses of the fifth lumbar vertebra will thus be trapped in a pincers-like grasp between the downward projecting inferior articular processes of the fourth lumbar vertebra and the upward projecting articular processes of the sacrum and will be subjected to tremendous pressure.

This concept is also supported by three of the special cases of spondylolysis. In Case 1, a lumbarized first sacral vertebra was affected; in Case 2, the fifth lumbar vertebra was sacralized and spondylolysis of the fourth lumbar vertebra was present; in Case 3, a supernumerary sixth lumbar vertebra was affected (Figs. 3-A through 3-C). In all these cases the position and relationship of the affected vertebra were those of a normally situated fifth lumbar vertebra and in all likelihood it was subjected to the same stresses and strains.

In skeletons anatomically conditioned or predisposed to spondylolysis, various other circumstances may promote the onset or hasten the progress of the spondylolytic process. These may be termed adjuvant or precipitating factors. Anything tending to flatten the lumbar intervertebral discs, exaggerate the lumbar lordosis, and approximate the vertebrae, particularly their neural arches, will favor the impingement of the articular processes against the isthmus and so promote the development of spondylolysis. Among these factors may be included the following: (1) trauma; (2) erect posture; (3) lifting and carrying heavy weights (a higher incidence of spondylolysis and spondylolysthesis has been observed in workers engaged in heavy manual work [24,57]); and (4) advancing age. Spondylolysis is not present at birth [5,6,43,71,73] and is infrequent in children [24,57,78,81]. Its incidence is higher in those in their twenties [73] and, according to Stewart [88], Friberg [24], Willis [97], and Runge [74], appears to increase with age. In our series of cases, the vast majority were in the vertebrae of individuals over fifty years of age, one being ninety-three and another one hundred and five years old. Nearly half of the total number of vertebral columns examined were of persons less than fifty years of age (Table I). These figures are too small to be statistically significant but they suggest that advancing age plays a role in the development of spondylolysis.

It is possible that advancing age exerts its effect by:

1. The accompanying degeneration and consequent flattening of the intervertebral discs [2,37,39,50,54,59,75,76,77,84]. (It is interesting to note the parallelism existing between the ages at which degenerative processes in the intervertebral discs [17,18,19,21] on the one hand, and spondylolysis [73] on the other, are said to develop.)

2. Osteoporosis of the vertebral column, resulting in varying degrees of flattening of the vertebral bodies [7,8,42,53].

Both have been found to be more pronounced in the lower lumbar region and both will tend to increase the pincers effect of the articular processes on the isthmuses subjected to their pressure. Osteoporosis of the isthmuses themselves may also render them more susceptible to pressure.

3. Relaxation of the muscles, ligaments, and articulations of the neural arches [83] as a result of flattening of the vertebrae and the intervertebral discs may well facilitate the chronic traumatic action of the articular processes.

There are sex and race differences in the incidence of spondylolysis. The incidence in females is less than in males (Table V), and the incidence in the Mongolian races [1,16,32,79,90], particularly Eskimos [86,87,88], is higher than in whites [72] in whom the condition is more frequent than in Negroes [72,82,83] (Table IV). These differences in incidence may be dependent on the presence of the conditioning anatomical factors previously described; these may be genetically determined. External environmental conditions, such as habits of the population and postural stresses, would then exert their effect through these anatomical factors. The geograhical differences in the incidence of spondylolysis in Eskimos may then be explained on the basis of the different environmental factors, including differences

in the physical terrain, as postulated by Stewart [86]. Similarly, in those instances in which spondylolysis has been described as familial [3,24,26,27], it would not be the spondylolysis itself which is inherited, but only the predisposing anatomical conditions.

Bone repair is characteristically lacking in spondylolysis; this is to be attributed to the persistence of the selfsame factor which, in the first instance, produced the lesions, that is, the pressure of the adjoining articular processes against the isthmus and their subsequent penetration into the cleft. Chandler [14] observed the relationship of these articular processes to the clefts in the isthmuses and recognized the importance of their separating effect. Shearing stress, pushing forward the free body of the affected vertebra [46,91], and the mobility of the separated neural arches [30,46] have also been regarded as factors preventing bone healing.

Periodicals and standard texts on spondylolysis still maintain that the condition is essentially due to failure of two ossification centers in each side of the vertebral arch to unite, or to some other congenital ossification defects [4,12,22,24,60,64,80]. However, it has been determined by numerous workers [6,14,24,30,33,38,43,52,71,97] that only one ossification center develops in each half of the neural arch, that spondylolysis is rarely present in foetuses or stillborn infants [5,6,38,43,70,73] and that it is also rare in young children [12,24,45,57,78,81]. It would appear, therefore, that the theory of the two centers of ossification as an explanation of the origin of spondylolysis can no longer be sustained and it is time that it was discarded. Accessory centers of ossification are occasionally found in the neural arch, but their presence in the anterior part of the pedicle [97], or the inferior articular processes [23,71], or in any other of the locations described [3,6,31,36] makes it impossible for them to have any connection with the development of spondylolysis.

Lambl's theory [47] of a primary fetal sacrolumbar hydrorachis as the cause of spondylolysis does not appear to be supported by the findings in this study.

Hitchcock's theory [38] of the production of spondylolysis by injury at, or shortly after, birth is negated by the rarity of spondylolysis in early childhood and has not been confirmed by the observations of Rowe and Roche [73]. Roberts [68] considers spondylolysis to be the result of a process of de-ossification due to overstrain at the pars interarticularis, his concept being similar to that of Brandt [11] and Henschel [34] in explaining the development of creeping fractures.

The direct relationship of the cleft in the isthmus to the inferior articular process of the vertebra above and to the superior articular process of the vertebra below—even with penetration of these processes into the cleft—has been noted by a number of workers [14,25,54] and is clearly seen in most of the published illustrations and roentgenograms of the condition [9,25,58,68]. However, these workers have ascribed no etiological significance to the articular processes in the initial production of the cleft. Capener [13] considered the pressure effect of the articular processes in the production of spondylolisthesis, but he too believed that they exert an effect on congenitally cleft isthmuses, producing a splitting of the already affected neural arches.

Lane [48] in 1885 and Meyer [55] in 1931, however, reached conclusions in their studies on the etiology of spondylolysis similar to those in the present study. Lane in his work on five cadavera with spondylolisthesis found, as we did, both the lesions and the relationship of the adjoining articular processes. He described instances in which the lamina showed signs of prolonged pressure, but no cleft of the neural arch. He said that he did not see any necessity to attribute any of the changes, which appear to be unmistakably produced by pressure alone, to an arrest of development, to fracture of the arch, or to dislocation of the articular processes.

Meyer [55] also gave a precise description of the relationship between the interarticular portion of the vertebra and the impinging articular processes. He, too, made use of the concept of a pincers effect and described intermediate stages, prior to the development of a cleft. Meyer [55] concluded that the so-called spondy-

lolysis congenita of Neugebauer [60] is always an acquired condition which develops in the basis of anatomical peculiarity in conjunction with lordosis of the lumbar spine and specific circumstances of pressure and movement. I am in essential agreement with this view.

In the light of the findings of the present study and of the interpretation of the development of spondylolysis, an important practical consideration arises: would it be possible to determine, roentgenographically or otherwise, which individuals are anatomically predisposed to the development of spondylolysis, and if so, to institute adequate preventive measures? Further studies are required to provide an answer to this problem.

SUMMARY

The nineteen cases of spondylolysis, in a series of 450 skeletons studied, have been classified into two groups: typical (sixteen cases) and atypical spondylolysis (two cases). One skeleton presented typical and atypical spondylolysis in different vertebrae. In typical spondylolysis, generally found in the lower lumbar vertebrae, the clefts of the isthmus were always located between the downward projecting inferior articular processes of the vertebra above and the upward projecting superior articular processes of the vertebra below. Such clefts appear to be produced by compression of the isthmuses by these articular processes in a mechanism termed a pincers effect. The presence of preceding bone abnormalities or congenital defects of the isthmus would seem to be unnecessary for the production of the lesions. The anatomical factors promoting the development of the condition in some individuals and those preventing its appearance in others are discussed. The participation of other factors, such as erect posture, trauma, age, sex, and race is also analyzed. Skeletons were found in which the development of spondylolysis had stopped before total separation of the vertebral arch had occurred; marked depressions were on the upper and lower surfaces of the isthmuses precisely at their sites of contact with the articular processes of the adjoining vertebrae. The term *prespondylolysis* has been applied to these cases. In atypical spondylolysis no direct relationship of the clefts to the articular processes of the vertebrae above and below was observed. In these cases the etiology could not be established.

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Results in the Treatment of Scoliosis with Turnbuckle Plaster Cast Correction and Fusion*

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This paper reports the author's experience with the surgical treatment of scoliosis at the University of Rochester Medical Center during two periods: 1939 to 1941, and 1946 to 1956. It is the result of a suggestion by Dr. R. Plato Schwartz to adopt a planned program for the treatment of scoliosis at the clinic. The form of therapy adopted was based on the work of several men [2,5,6,9] with later modifications [3,4]. I, personally, treated and followed all patients.

MATERIAL

Sixty consecutive patients were treated by turnbuckle plaster cast correction and spine fusion. Six of these patients were treated too recently to evaluate final results. The fifty-four remaining patients were analyzed in relation to the following points: (1) preoperative correction of the curve and maintenance of that correction; (2) the technique of spine fusion; and (3) the incidence of pseudarthrosis.

Sufficient time has elapsed in fifty-four patients to allow evaluation of the fusion and the degree of loss of correction in the fused segment of the spine. Fifty-one patients were followed for two years or more, two for eighteen months, and one for fourteen months.

The patients with idiopathic scoliosis were grouped according to the classification described by Ponseti and Friedman and according to James' prognostically significant subgrouping of the main thoracic-curve pattern.

There were sixty patients with structural scoliosis. Of the thirty-five with idiopathic scoliosis, one patient had a main lumbar curve; six, thoracolumbar curve; five, combined thoracic and lumbar curve; and twenty-three, main thoracic curve. There were nine cases of juvenile scoliosis (onset between the ages of five and ten years), and fourteen cases of adolescent scoliosis (onset after the age of ten). Twenty-one patients had paralytic and four patients had congenital scoliosis.

The indications for operation in the cases of idiopathic scoliosis were the following: an increasing deformity before growth of the spine was complete, an unsightly deformity at or after maturity which could be corrected, and pain (the presenting complaint in two adult patients). In the four patients with congenital scoliosis, surgery was performed because of the degree of deformity, and in twenty-one patients with paralytic scoliosis, progression of the curve, degree of deformity, and instability of the trunk due to muscle weakness were the indications for surgical treatment.

The age of the patients at the time of operation varied from eight years and eleven months to twenty-six years (Chart I). There was only one patient under ten years of age. Two patients were in the tenth year, four in the eleventh, and seven in the twelfth year. Thirty-six patients (66 per cent) were between thirteen and seventeen years of age. Four patients were over eighteen.

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FIG. 1

Anteroposterior roentgenograms of the spine showing the patient supine, standing, bending to the right, bending to the left for an upper thoracic curve, and bending to the left for a lumbar curve.

The distribution of patients according to severity of the curve is shown in Chart II. Seventy-five per cent of the curves measured 70 degrees or more.

METHOD OF TREATMENT

When surgical treatment is necessary, the following procedure is the method of choice. A complete roentgenographic survey of the entire spine is made (Fig. 1)[3]. This includes anteroposterior roentgenograms of the vertebral column made with the patient supine, standing, bending to the right, and bending to the left. The views of the patients in the supine and standing positions are made on fourteen by thirty-six-inch films to include the entire spine. The angle of the curve is measured on an anteroposterior roentgenogram as determined by Cobb[3]. Two lines are drawn; one marking the superior surface of the top vertebra and the other, the inferior surface of the distal vertebra involved in the primary curve. The angle formed at the intersection of two lines drawn perpendicular to the markers is the angle of the curve. The preoperative deformity is determined by measuring the curve on the roentgenogram made with the patient standing. The roentgenograms made with the patient bending allow determination of the degree of fixed angular deformity in the counter curves, as well as an

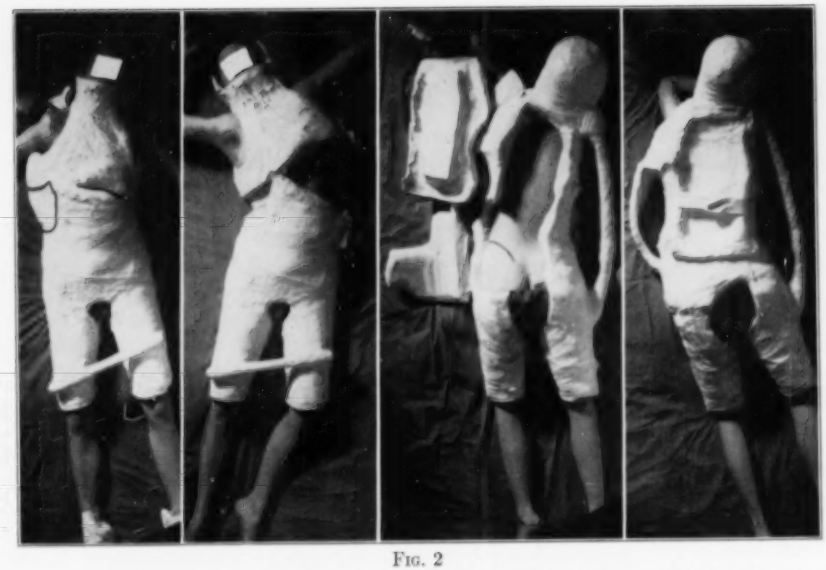

FIG. 2

The turnbuckle plaster cast is shown on the left before correction is started. The center photographs show turnbuckle wedging in progress and the large posterior window through which spine fusion is performed. On the right the lids are in place and the patient is ready to be discharged from the hospital, two to three weeks after surgery.

estimation of the relative ease with which the primary curve can be corrected. From this data, the allowable correction is determined. In general, the angle of the primary curve is not corrected beyond the sum of the angles of the compensatory counter curves.

The deformity is corrected preoperatively in a turnbuckle plaster cast which includes the head and both thighs (Fig. 2). A spine marker roentgenogram is made after the desired correction has been obtained to allow accurate placement of the fusion. This is done by injecting one milliliter of sterile methylene blue into the skin, the subcutaneous tissue, and the tip of a spinous process at or near the distal end of the proposed fusion area. An opaque marker is placed on this spot and a roentgenogram is made.

I have followed the generally accepted principle that all the vertebrae in the primary curve must be included in the fusion. The belief that the fusion should extend beyond the primary curve varies. This paper does not include a discussion of the problem of the area of fusion.

THE FUSION OPERATION

The technique of spine fusion has remained essentially the same during this surgical experience with two minor variations. First, additional experience has resulted in better technical performance and, therefore, better fusions in patients operated upon recently; in the past five years, the spine has been exposed more widely than previously. Second, the type of supplementary bone added to the fusion area has been changed. From 1939 to 1947, tibial osteoperiosteal grafts were used. Bone-bank bone chips were used as supplements in a group of patients treated from 1948 to 1951. Since early in 1952, fresh autogenous iliac bone has been used almost exclusively.

The operation is performed through a large posterior window in the turnbuckle plaster cast (Fig. 2). Adrenalin solution, 1:200,000 in physiological saline, which acts as a hemostatic agent, is injected into subcutaneous and fascial tissue along the line of the proposed incisions over the ilium and spine [10]. The

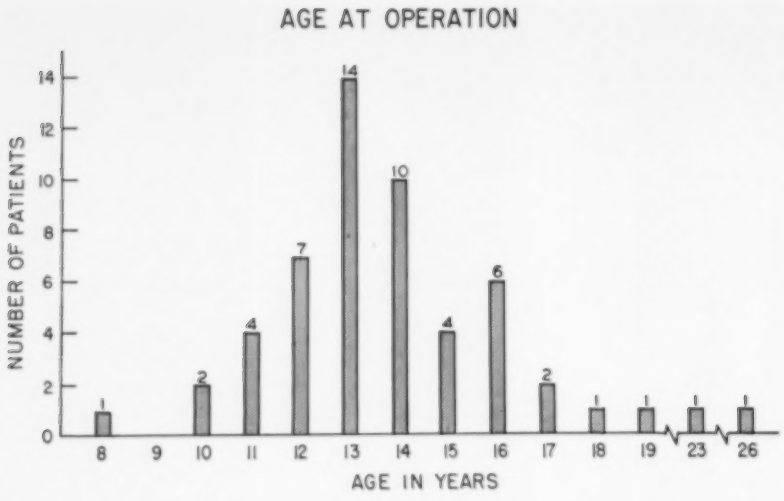

CHART I

ilium is then widely exposed subperiosteally through an incision parallel to the posterior two-thirds of the iliac crest. Rectangles of cortex are removed from the posterior two-thirds of the outer table of the ilium (Fig. 3). With a hand gouge, long strips of cancellous bone are peeled off the ilium from the entire exposed surface. A large quantity of supplementary bone is thus obtained for use during fusion. The blocks of cortical bone are cut into slivers four to six centimeters long, and the strips of cancellous bone are used as removed. This wound is closed to the subcutaneous tissue.

The spine is then exposed through a straight linear incision on the concave side of the corrected curve as suggested by Cobb [4]. The soft-tissue structures are reflected subperiosteally from the spinous processes and laminae; the exposure is carried out over the transverse processes in the thoracic spine (Fig. 4) and over the posterior articulations in the lumbar area. All soft tissue is meticulously removed and the tips of the spinous processes are clipped off. Then, with a

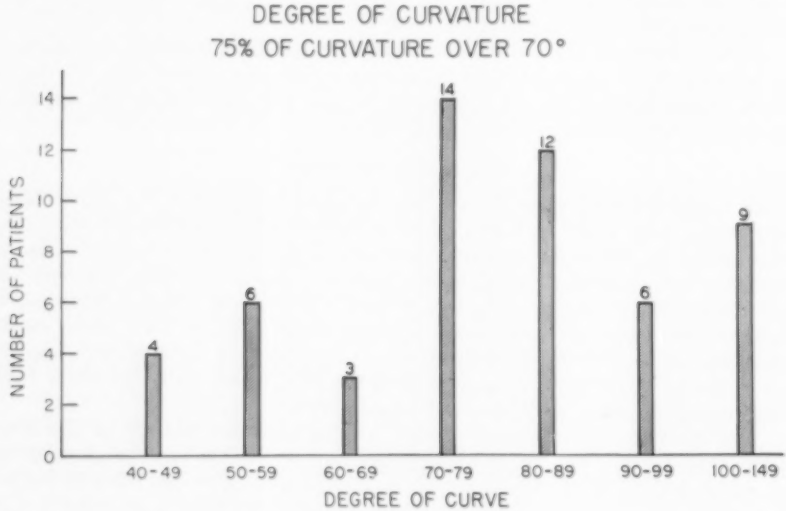

CHART II

sharp hand gouge, bone flaps are turned down from the spinous processes, laminae, and transverse processes. Deep cuts are made, reflecting the full thickness of the posterior cortex of the lamina and transverse process and turning down the entire spinous process exposing maximum width of raw bone surface. The flaps of bone thus obtained are laid down along the more lateral aspects of the fusion area, covering the interlaminar spaces with the cortical side of the bone flap turned ventrally. No attempt is made to interlock the bone flaps, to keep them attached at their base, or to preserve any portion of the spinous process of the end vertebrae. In the lumbar spine the bone flap is carried as far laterally as possible, crossing the exposed posterior articulations. The iliac bone, first cancellous then cortical, is laid down over the fusion area.

The use of the mallet is avoided because it is thought that it contributes to the onset of shock. The hand-gouge technique and replacement of blood as it is lost, usually three pints during surgery, have permitted routine one-stage operations. I was first introduced to the hand-gouge technique of spine fusion in 1937 at the Massachusetts General Hospital [1].

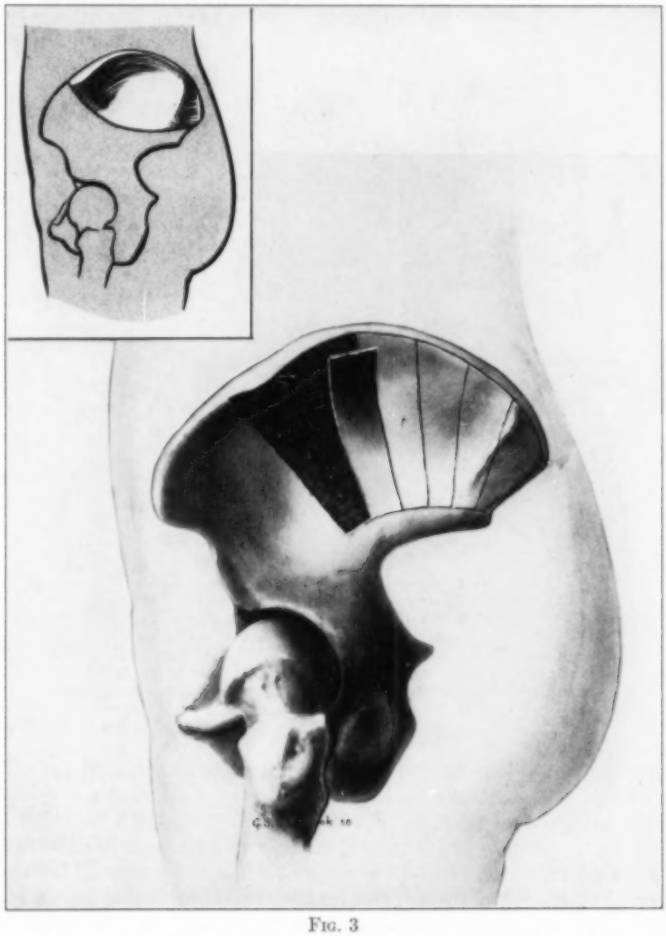

FIG. 3

This diagram shows the donor site of the graft. Exposure of the posterior two-thirds of the outer table of ilium is shown in the insert. Cortical rectangles are first removed and then all the exposed underlying cancellous bone taken from the ilium.

Seven to nine vertebrae, with eleven in two patients, has been the most common number of vertebrae fused in one stage. Forty patients in this series had one-stage fusion operations. Eight patients required two stages, and in one patient a three-stage procedure was performed. In four patients, bone was removed from both iliac crests and placed in the bone bank before application of the turnbuckle cast. After correction of the curvature in the turnbuckle cast, the banked autogenous iliac bone was used during spine fusion which was performed in one stage.

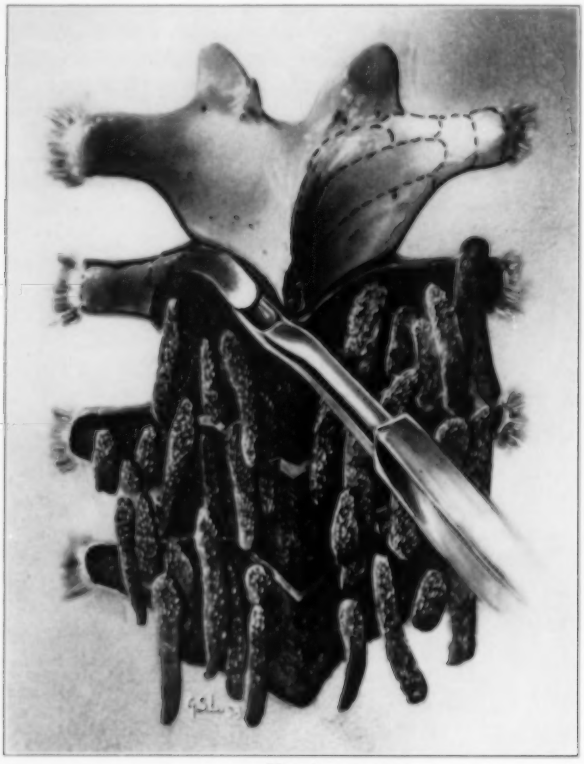

FIG. 4

Composite diagram showing the technique of fusion. There is complete decortication of laminae and transverse processes, and the spinous processes are turned down. Bone flaps are detached and laid down over the more lateral aspects of the fusion area. The supplementary cancellous and cortical iliac-bone grafts are then laid down over the entire area; these grafts are not shown.

POSTOPERATIVE TREATMENT

Immobilization in the turnbuckle plaster cast is maintained for six months postoperatively. The patients usually are discharged from the hospital two to three weeks after operation. The New York State Crippled Children's Program provides a home tutor so that education is not significantly interrupted. Six months after operation the patient is readmitted to the hospital, the turnbuckle cast removed, and the status of the fusion evaluated roentgenographically. A bent cast (Fig. 5), which surrounds one thigh and has a single shoulder strap, is applied and then worn for two additional months in a recumbent position at home. A bent cast adapted for walking and having one shoulder strap is worn for another two months (Fig. 5). The patient is then freed of all sup-

port. In several of the patients with paralytic scoliosis and severe trunk involvement, a removable celluloid jacket was worn for longer periods.

RESULTS OF OPERATION

The maximum preoperative deformity is the angle measured on a roentgenogram of the spine made with the patient standing. The correction obtained is the difference between the original curve and corrected curve measured on the last preoperative roentgenogram made with the plaster lid removed. All correction is obtained before fusion is performed. The degree of loss of correction is determined by measuring the curve in the most recent roentgenogram made with the patient standing without support.

The presence of pseudarthrosis is suspected when significant and progressive loss of correction is observed on anteroposterior roentgenograms of the spine. Oblique roentgenograms of the spine were made to visualize the fusion mass more clearly and to detect lines of decreased density indicative of pseudarthrosis.

As stated earlier in this paper, these patients were evaluated particularly in relation to spine fusion, the incidence of pseudarthrosis, and the loss of correction. The scoliotic deformity, as a whole, is not under consideration in this paper. An additional detailed follow-up study of the over-all changes in the spine following correction and fusion is being prepared.

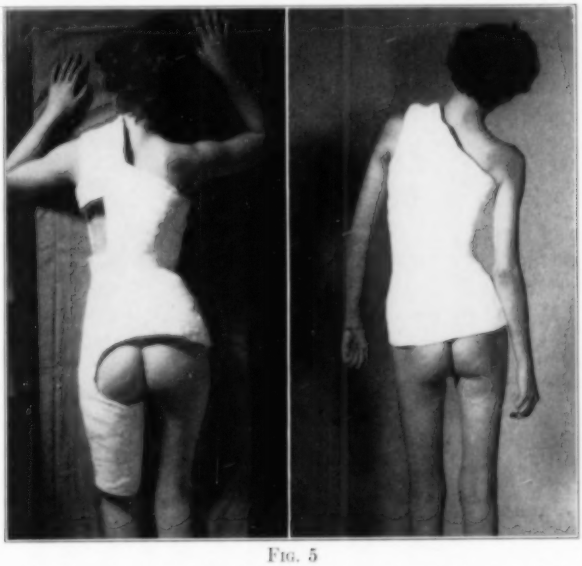

FIG. 5

Photograph (left) of a bent plaster cast applied six months postoperatively. Eight months after surgery a bent plastic cast adapted for walking is applied (right).

PSEUDARTHROSIS

In fifty-four consecutive cases there were seven instances of pseudarthrosis, an incidence of 12.9 per cent. Pseudarthrosis occurred in two of the three patients with congenital scoliosis. One patient, in whom a supplementary osteoperiosteal-bone graft was used with fusion, had wide spina bifida extending from the tenth thoracic vertebra to the sacrum. Another patient who had spine fusion with bone-bank bone had poorly developed posterior vertebral-arch structures; these formed a poor base for satisfactory fusion. The results in these cases are not truly representative of the method.

TABLE I

PARALYTIC SCOLIOSIS

Case	Original Curve (*Degrees*)	Preoperative Curve (*Degrees*)	Extent of Fusion*	Final Primary Curve (*Degrees*)	Follow-up (*Yrs. and Mos.*)	Preoperative Correction† (*Per cent*)	Loss of Correction†† (*Per cent*)	Age at Operation (*Yrs. and Mos.*)	Time Recumbent (*Mos.*)	Type of Graft	Status of Fusion
E. C.	143	64	2 + (T8 to L4) + 2	87	9 + 9	55	29	16	9	Osteoperiosteal	Pseudarthrosis repaired
N. H.	120	73	1 + (T5 to T12) + 3	85	17	39	25	19	6	Osteoperiosteal	Solid
G. O.	73	20	(C7 to T10) + 1	21	6 + 8	73	2	13 + 2	5	Osteoperiosteal	Solid
P. F.	55	15	(T3 to T11) + 1	28	9 + 10	73	32	10 + 9	6½	Osteoperiosteal	Solid
R. W.	65	10	(T3 to L3) + 3	27	5 + 6	85	31	18 + 6	9	Bone-bank bone	Solid
N. Mon.	54	13	(T9 to L3) + 1	20	4 + 4	76	17	14 + 11	6½	Osteoperiosteal and bone-bank bone	Solid
C. Cl.	76	22	1 + (C7 to T8) + 2	30	9 + 2	71	15	15	6	Bone-bank bone	Solid
B. J.	79	29	1 + (T8 to L3) + 1	84	6	63	100	12 + 8	8	Bone-bank bone	Pseudarthrosis
L. La.	120	70	2 + (T3 to T11) + 2	85	6	42	30	13 + 8	10	Osteoperiosteal and bone-bank bone	Solid
C. Rob.	77	22	1 + (T7 to L2) + 1	27	5	71	9	13	7	Fresh autogenous iliac and bone-bank bone	Solid
L. Ba.	97	50	(T2 to T10)	67	4 + 9	48	36	10 + 6	9	Banked autogenous iliac bone	Solid
T. F.	75	30	1 + (T6 to T12) + 1	38	4	60	18	14 + 5	9	Fresh autogenous iliac bone	Solid
C. So.	93	48	(T6 to L2)	65	3	48	38	23	9	Banked autogenous iliac bone	Solid
C. Rot.	82	45	1 + (T1 to T12) + 1	65	3 + 10	45	54	17	9	Banked autogenous iliac bone	Solid
C. Ron.	100	32	1 + (T1 to T12)	45	3 + 10	68	19	13 + 8	10	Banked autogenous iliac bone	Solid
N. Mc.	63	18	1 + (T8 to L3)	16	2 + 6	71	0	15 + 5	7	Autogenous iliac bone	Solid
G. Lin.	83	15	1 + (T9 to L3)	20	2 + 6	82	7	14 + 11	9	Autogenous iliac bone	Solid
D. Kr.	87	23	1 + (T5 to T11)	31	2 + 6	73	12	16	6	Autogenous iliac bone	Solid
B. Mu.	95	28	2 + (T9 to L3)	32	2 + 6	70	6	11 + 5	6½	Autogenous iliac bone	Solid
C. K.	122	70	(T10 to L3)	73	4	43	6	16	8½	Autogenous iliac and bone-bank bone	Solid

* Primary curve is in parentheses; numbers outside parentheses indicate additional vertebrae included in the fusion.

† Preoperative correction (per cent) = $\frac{\text{Original curve} - \text{Preoperative curve (total correction obtained)}}{\text{Original curve}} \times 100$

‡ Loss of correction (per cent) = $\frac{\text{Final curve} - \text{Preoperative curve}}{\text{Total correction obtained (original curve} - \text{preoperative curve)}} \times 100$

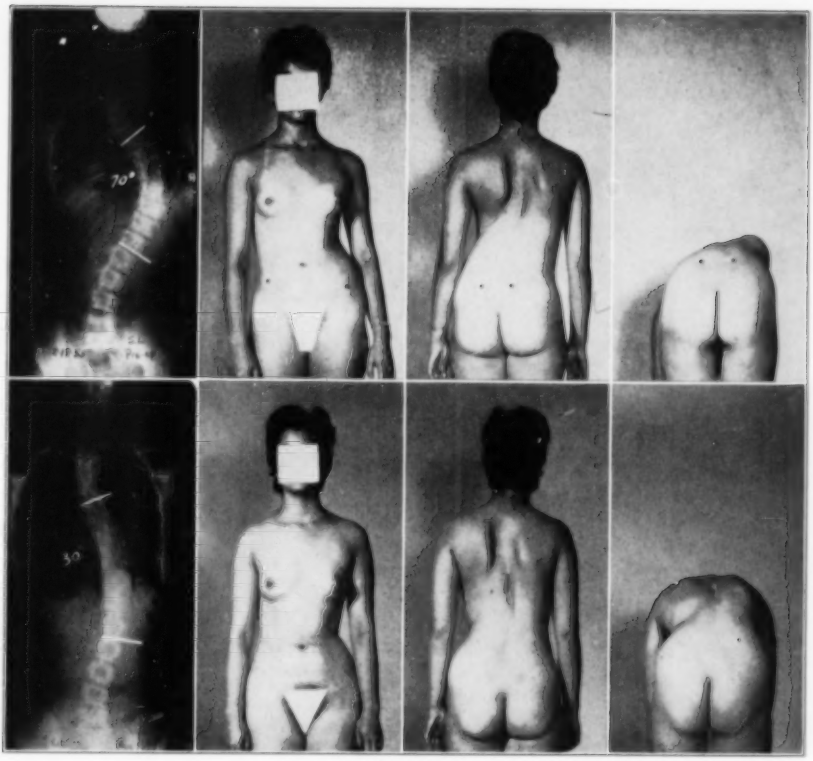

FIG. 6

Case S. L. Idiopathic scoliosis, thoracic curve. This patient was the only one in whom pseudarthrosis developed in the group of patients who had grafts of fresh autogenous iliac bone applied during fusion. Pseudarthrosis healed spontaneously. The preoperative photographs are seen at the top; those at the bottom were made two years postoperatively.

Of thirty-one patients with idiopathic scoliosis, pseudarthrosis developed in three; in twenty with paralytic curvatures, pseudarthrosis developed in two. The incidence of pseudarthrosis and the loss of correction in the fifty-one patients with idiopathic and paralytic scoliosis have been studied in relation to the type of supplementary bone used in fusion and are divided into two main categories.

1. *All other types of bone grafts:* This group includes patients who had tibial osteoperiosteal-bone grafts, homogenous bone-bank bone chips, banked autogenous iliac bone, or a combination of any two of these used in fusion (Tables I, II, and III). There were four instances of pseudarthrosis (15.3 per cent). Of the twenty-six patients in this category who had loss of correction, fifteen lost 15 degrees of correction or less. Seven patients lost between 16 degrees and 24 degrees. Four patients with pseudarthrosis showed the following losses: 23 degrees, 31 degrees, 55 degrees, and 57 degrees, respectively.

2. *Fresh autogenous iliac-bone grafts:* In these patients, a massive amount of supplementary fresh autogenous iliac bone, both cortical and cancellous, was used in fusion. Of the twenty-five consecutive patients, there was one instance of pseudarthrosis (4 per cent) (Table IV). This pseudarthrosis, Case S. L., occurred at the last joint in the fused area of a thoracic curve in a patient with idiopathic scoliosis (Fig. 6). The pseudarthrosis healed spontaneously with only a 14-degree loss of correction; this occurred almost entirely during the three-month period following removal of the plaster support. Twenty-four patients lost

TABLE II

IDIOPATHIC SCOLIOSIS—MAIN THORACIC CURVE

Case	Original Curve (*Degrees*)	Preoperative Curve (*Degrees*)	Extent of Fusion*	Final Primary Curve (*Degrees*)	Follow-up (*Yrs. and Mos.*)	Preoperative Correction (*Per cent*)	Loss of Correction (*Per cent*)	Age at Operation (*Yrs. and Mos.*)	Time Recumbent (*Mos.*)	Type of Graft	Status of Fusion
M. V.	50	8	1 + (T6 to T12)	16	17 + 8	84	19	15 + 4	4	Osteoperiosteal	Solid
A. H.	45	3	1 + (T6 to T12)	0	4 + 9	93	0	8 + 11	4	Osteoperiosteal	Solid
J. B.	87	25	1 + (T6 to L1)	56	9	71	50	17	5	Osteoperiosteal	Pseudarthrosis
D. H.	58	5	1 + (T6 to T12) + 1	12	6	91	13	11 + 6	4	Osteoperiosteal	Solid
J. M.	110	52	1 + (T4 to T12) + 2	50	6	53	0	12 + 11	9	Osteoperiosteal and bone-bank bone	Solid
P. W.	148	85	2 + (T5 to T12) + 3	98	5 + 8	42	21	14 + 7	9	Fresh autogenous iliac and bone-bank bone	Solid
D. G.	67	20	(T5 to 12)	30	4 + 5	70	21	13	9½	Fresh autogenous iliac bone	Solid
S. Ry.	71	34	1 + (T7 to T11)	38	4	52	11	12 + 10	8	Fresh autogenous iliac bone	Solid
D. St.	76	29	1 + (T6 to T12) + 1	35	3 + 1	67	12	13 + 6	9½	Fresh autogenous iliac bone	Solid
D. R.	87	40	1 + (T5 to T11)	52	3 + 3	54	25	14 + 9	8½	Fresh autogenous iliac bone	Solid
A. Hag.	74	15	1 + (T6 to T12)	20	3	80	8	13	8	Fresh autogenous iliac bone	Solid
L. M.	90	42	1 + (T6 to L1)	47	2 + 11	53	10	13 + 5	8	Fresh autogenous iliac bone	Solid
S. L.	70	16	1 + (T6 to L1)	30	2 + 9	77	26	14 + 10	6½	Fresh autogenous iliac bone	Pseudarthrosis healed
D. Sey.	75	33	(T6 to L1)	56	1 + 6	56	55	15 + 3	6	Fresh autogenous iliac bone	Solid
T. He.	87	27	(T5 to T12)	37	2 + 6	69	17	13 + 11	6	Fresh autogenous iliac bone	Solid
A. S.	83	17	1 + (T6 to L1)	20	2 + 6	79	4	12 + 5	6	Fresh autogenous iliac bone	Solid
A. I.	90	30	(T4 to T12)	38	2 + 4	67	13	11 + 6	6	Fresh autogenous iliac bone	Solid
J. W.	87	46	(T6 to T12)	45	2	47	0	12 + 8	8	Fresh autogenous iliac bone	Solid
C. Tin.	80	41	1 + (T5 to T11) + 1	43	2	49	5	16 + 4	6	Fresh autogenous iliac bone	Solid
R. H.	82	43	(T5 to T12)	44	2	47	2	14 + 7	8	Fresh autogenous iliac bone	Solid
B. C.	73	18	(T5 to T12)	23	1 + 6	75	9	13 + 11	8	Fresh autogenous iliac bone	Solid

* Primary curve is in parentheses; numbers outside parentheses indicate additional vertebrae included in the fusion.

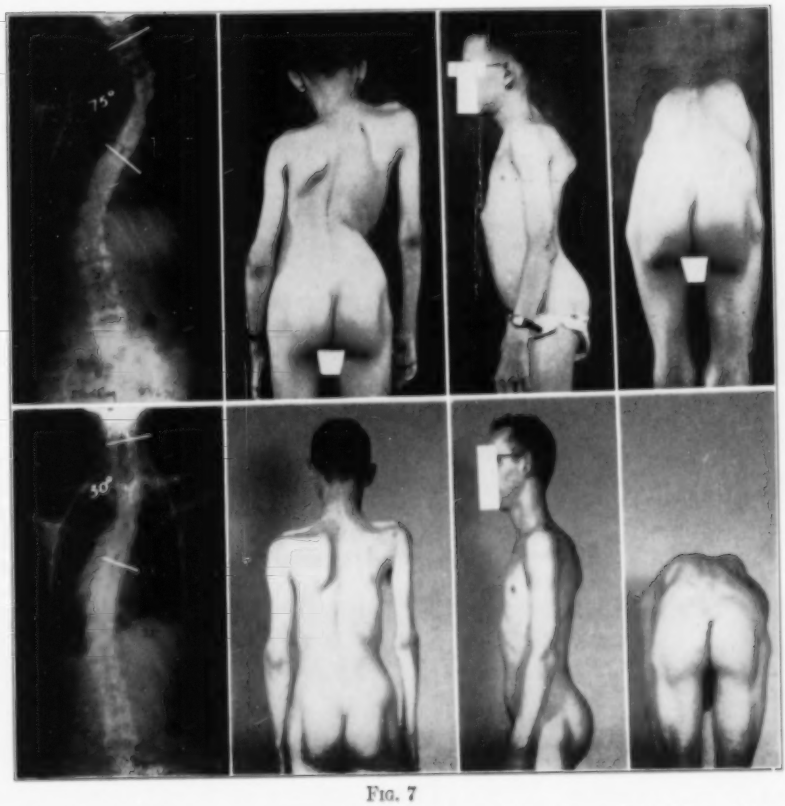

FIG. 7

Case C. Cl. Paralytic scoliosis, cervicothoracic curve. Two-stage spine fusion was performed when the patient was fifteen. Bone-bank bone grafts were applied to the fusion area which included the primary curve, one vertebra above, and two below. The top photographs show the patient before correction; the bottom ones show him eight years post-operatively.

15 degrees or less of correction. In twenty-two patients, the loss of correction was 10 degrees or less. The curve in one patient (Case D. Sey., Table IV) had a 23-degree loss.

Case S. L., the one patient in whom pseudarthrosis developed in the group of patients in whom fresh, autogenous iliac-bone grafts were used to supplement fusion, walked six months after operation. Because solid massive fusion was observed in the oblique roentgenograms made at the time of removal of the turnbuckle cast, several patients were allowed to walk six months after operation. However, after observing the results in two patients (Cases D. Sey. and S. L.) who walked after six months, the routine of eight months in a recumbent position was again adopted and is still being practiced regardless of the roentgenographic appearance of the fusion mass at six months.

With the exception of Cases D. Sey. and S. L., no loss greater than 6 degrees was measured in the fusion area in this group of patients after the first postoperative year. It is evident, therefore, that this type of fusion is sufficiently mature at the end of the first postoperative year to hold correction without further significant loss. There was no graft fracture or so-called delayed pseudarthrosis observed after the first postoperative year.

TABLE III

IDIOPATHIC SCOLIOSIS

Case	Curve Pattern	Original Curve (*Degrees*)	Preoperative Curve (*Degrees*)	Extent of Fusion*	Final Primary Curve (*Degrees*)	Follow-up (*Yrs. and Mos.*)
L. P.	Lumbar	52	7	(T10 to L4)	17	10 + 6
M. J.	Thoracolumbar	42	16	(T9 to L3) + 1	40	15 + 3
K. H.	Thoracolumbar	76	17	(T8 to L2)	33	5 + 9
N. C.	Thoracolumbar	68	16	(T7 to L2)	17	4 + 6
R. M.	Thoracolumbar	95	31	(T7 to L2)	88	4

* Primary curve is in parentheses, number outside parentheses indicates additional distal vertebra included in the fusion.

COMPLICATIONS

Three major postoperative wound infections occurred. In two patients, fusion was solid with maintenance of correction; in a third patient pseudarthrosis developed with subsequent loss of correction. Compression of the brachial plexus with partial motor and sensory loss, due to pressure of the headpiece against the left side of the neck, occurred in two patients early in my experience in treating

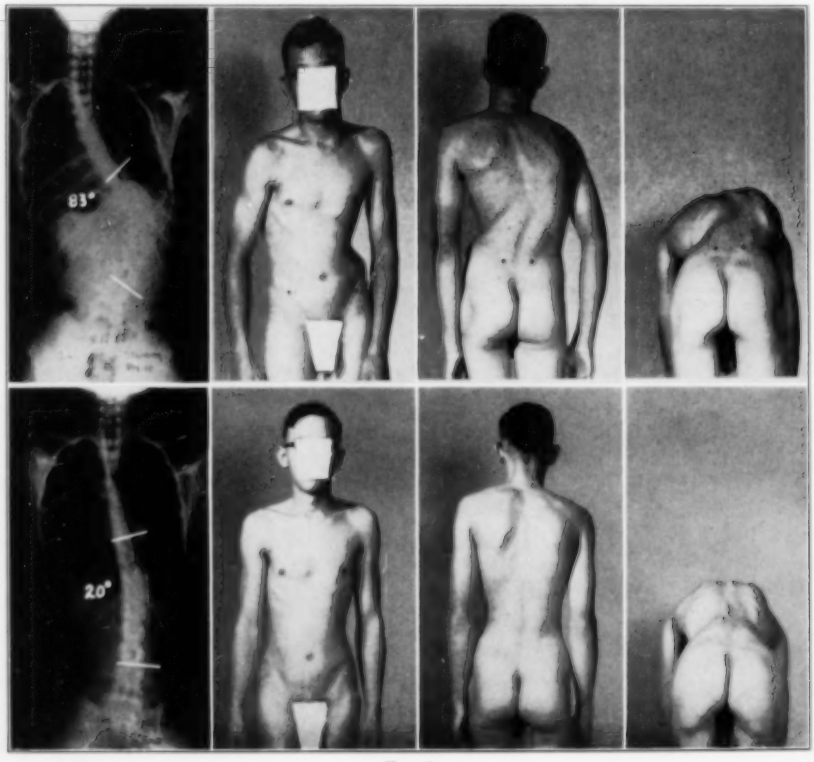

FIG. 8

Case G. Lin. Paralytic scoliosis, thoracolumbar curve. One-stage spine fusion which included the primary curve and one vertebra above was performed when the patient was fourteen years and eleven months old. Fresh autogenous iliac bone was used for grafting. Preoperative photographs are seen on top; the bottom photographs were made two years postoperatively.

TABLE III

IDIOPATHIC SCOLIOSIS

Preoperative Correction (*Per cent*)	Loss of Correction (*Per cent*)	Age at Operation (*Yrs. and Mos.*)	Time Recumbent (*Mos.*)	Type of Graft	Status of Fusion
86	22	13 + 2	5	Osteoperiosteal	Solid
62	92	26	4	Osteoperiosteal	Solid
78	27	14	8	Bone-bank bone	Solid
76	2	16	8	Fresh autogenous iliac bone	Solid
67	89	13 + 1	9	Bone-bank bone	Pseudarthrosis

these patients. Complete and prompt recovery followed release of pressure. Flexion of the neck toward the concavity of the primary curve when applying the turnbuckle cast and careful attention to the molding of the plaster around the head and neck have eliminated this complication. In several of my early patients, deep pressure areas developed; with experience, this is no longer a problem.

Malocclusion, which is apt to occur because of the distracting force exerted during wedging of the turnbuckle cast, is prevented by a regular routine of jaw exercise done by the patients throughout the period of immobilization in the turnbuckle cast.

In one patient, respiratory difficulty, requiring a tracheotomy, developed five hours postoperatively. Removal of the tracheotomy tube nine days later was followed by uneventful recovery.

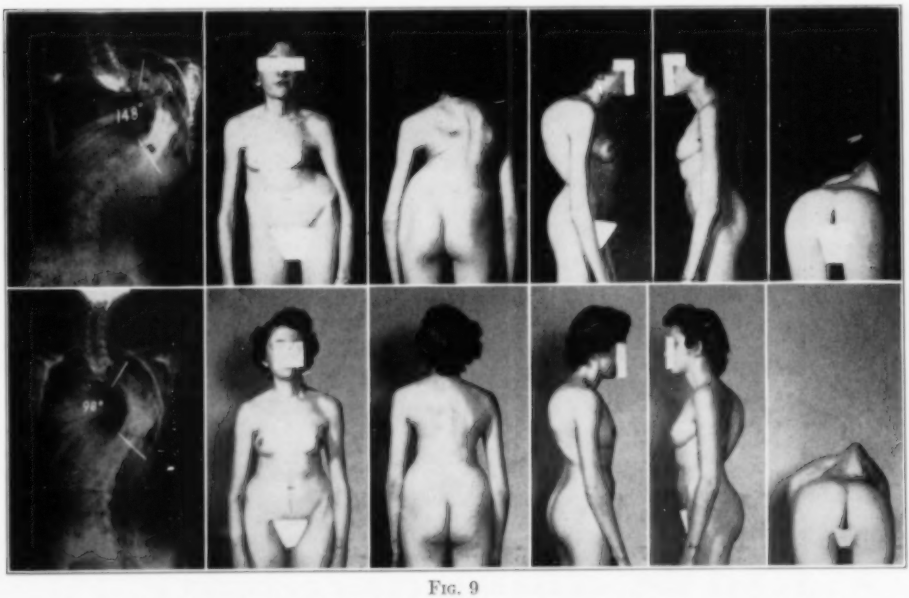

FIG. 9

Case P. W. Idiopathic juvenile scoliosis, main thoracic curve. Two-stage spine fusion between parallel vertebrae included the primary curve, two vertebrae above, and three below, and was performed when the patient was fourteen years and seven months old. The first stage was supplemented with fresh autogenous iliac bone and the second stage with bone-bank bone. The photographs at the top were made preoperatively. At the bottom, the patient is shown four years and nine months postoperatively. There is satisfactory correction of severe rigid curvature; the rotation deformity remains unchanged, as expected.

TABLE IV

FUSION WITH FRESH AUTOGENOUS ILIAC BONE

Case	Original Curve (*Degrees*)	Preoperative Curve (*Degrees*)	Final Primary Curve (*Degrees*)	Follow-up (*Yrs. and Mos.*)	Preoperative Correction (*Per cent*)	Loss of Correction (*Per cent*)	Age at Operation (*Yrs. and Mos.*)	Time Recumbent (*Mos.*)	Status of Fusion	Etiology
N. C.	68	16	17	4 + 6	76	2	16	8	Solid	Idiopathic
C. K.	122	70	73	4	43	6	16	8½	Solid	Paralytic
D. G.	67	20	30	4 + 5	70	21	13	9½	Solid	Idiopathic
S. Ry.	71	34	38	4	52	11	12 + 10	8	Solid	Idiopathic
D. St.	76	29	35	3 + 1	67	15	13 + 6	9½	Solid	Idiopathic
D. R.	87	40	52	3 + 3	54	25	14 + 9	8½	Solid	Idiopathic
A. Hag.	74	15	20	3	80	8	13	8	Solid	Idiopathic
L. M.	90	42	47	2 + 11	53	10	13 + 5	8	Solid	Idiopathic
S. L.	70	16	30	2 + 9	77	26	14 + 10	6½	Pseudarthrosis	Idiopathic
D. Sey.	75	33	56	1 + 6	56	55	15 + 3	6	Solid	Idiopathic
T. He.	87	27	37	2 + 6	69	17	13 + 11	6	Solid	Idiopathic
A. S.	83	17	20	2 + 6	79	4	12 + 5	6	Solid	Idiopathic
A. I.	90	30	38	2 + 4	67	13	11 + 6	6	Solid	Idiopathic
C. Tin.	80	41	43	2	49	5	16 + 4	6	Solid	Idiopathic
P. Cam.	108	60	70	5 + 8	44	21	12 + 11	9½	Solid	Idiopathic
L. Ric.	93	53	56	2 + 6	43	7	12 + 6	6	Solid	Idiopathic
C. Rob.	77	22	27	5	71	9	13	7	Solid	Paralytic
T. F.	75	30	38	4	60	18	14 + 5	9	Solid	Paralytic
N. Mc.	63	18	16	2 + 6	71	0	15 + 5	7	Solid	Paralytic
G. Lin.	83	15	20	2 + 6	82	7	14 + 11	9	Solid	Paralytic
D. Kr.	87	23	31	2 + 6	73	12	16	6	Solid	Paralytic
B. Mu.	95	28	32	2 + 6	70	6	11 + 5	6½	Solid	Paralytic
J. W.	87	46	45	2	47	0	12 + 8	8	Solid	Idiopathic
R. H.	82	43	44	2	47	2	14 + 7	8	Solid	Idiopathic
B. C.	73	18	23	1 + 6	75	9	13 + 11	8	Solid	Idiopathic

Another patient had massive gastro-intestinal hemorrhage on the eighth postoperative day. Ten pints of blood were required to stabilize the blood pressure over a twenty-four-hour period. The preoperative diagnosis was stress ulcer, but at operation a severe hemorrhagic gastritis was found. A subtotal gastrectomy was followed by uneventful recovery.

There were no deaths in this group of fifty-four patients.

SUMMARY

1. Pseudarthrosis occurred in seven patients (12.9 per cent) of the fifty-four patients reported.

2. Fifty-one patients with idiopathic and paralytic scoliosis were analyzed in relation to the type of supplementary bone graft used in the fusion. In twenty-six patients in whom osteoperiosteal, bone-bank bone, or a combination of these two types of supplementary grafts were used, pseudarthrosis occurred in four (15.3 per cent).

3. In twenty-five patients in whom fresh, autogenous iliac-bone grafts were used, pseudarthrosis occurred once (4 per cent). This pseudarthrosis healed spontaneously with only a 14-degree loss of correction. It should be noted that by the use of fresh autogenous iliac-bone grafts, the incidence of pseudarthrosis was significantly reduced. Twenty-four of these twenty-five patients lost 15 degrees or less of correction. In twenty-three of these twenty-five patients, there was no loss greater than 6 degrees recorded after the first postoperative year.

4. A carefully performed spine fusion with use of a large amount of supplementary fresh autogenous iliac bone results in prompt formation of a massive solid fusion which is fully mature at one year.

NOTE: A monograph "Surgical Treatment of Scoliosis" by the author will soon be published by Charles C. Thomas in the American Lecture Series.

ADDENDUM

As of December 1958, fifteen additional patients (making a total of seventy-five) have been treated by means of turnbuckle plaster cast correction and spine fusion. Ten of the fifteen patients, with idiopathic and paralytic scoliosis, have been followed between one to two years after operation. There are no pseudarthroses in these ten additional patients. In a total of thirty-five consecutive patients in whom fresh autogenous iliac bone has been used to supplement the fusion, there is one pseudarthrosis (an incidence of 3 per cent). There are no pseudarthroses in the last twenty-seven consecutive patients treated by means of this technique.

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Charcot Disease of the Spine

A Report of Two Cases Treated by Spine Fusion

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Jean Martin Charcot, the great French neuropathologist, is credited with describing and relating the etiology of neurotrophic arthropathies to lesions of the central nervous system. In 1868, he published his classic paper on spinal lesions. An American, John Kearsley Mitchell, apparently was the first to describe neurotrophic spinal arthropathies in 1831, but it was Charcot, Bekhtereff, Strümpell, and Marie who analyzed and related the conditions thirty-seven years later. Since these early investigators, much has been written concerning the pathology, etiology, diagnosis, and treatment of the various diseases of the central nervous system and their associated joint changes.

Charcot joints occur in from 4 to 10 per cent of all tabetic patients and, when present, are usually in the weight-bearing joints of the spine and lower extremities. The spine apparently becomes involved in about 10 to 15 per cent of patients with known Charcot arthropathies. In about one-third of the patients studied, more than one joint is involved. In about 25 per cent of patients with syringomyelia, neurotrophic joints develop; these are predominantly (80 per cent) in the upper extremities [5]. Steindler, in 1931, reported a series of sixty-four cases of Charcot disease in which 62 per cent of the patients were male and eight patients had spine involvement.

The exact pathogenesis of joint changes is still disputed. The most accepted theory is that the afferent proprioceptive nerves of the involved joint are destroyed, rendering the joint unable to compensate for repeated injury or minor trauma. Key and several other authors felt that there must be an additional factor, perhaps local connective-tissue changes, involving all the structures about the joint. Spontaneous or pathological fracture of the affected joint is known to be one of the first signs prompting the patient to seek medical advice. By the time original roentgenograms are made, extensive changes have frequently occurred. It is probable that a series of subclinical, painless pathological fractures or infractions had taken place prior to the first examination. These unrecognized injuries receive no treatment and undergo further disintegration because of continued weight-bearing and stress. New bone is noted in the disintegrated areas when the patient is first examined for a more severe or painful injury.

In a patient with lesions of the spine, weakness and deformity are the first symptoms noted, but when the patient seeks medical aid it is usually for pain in the back, pelvic girdle, or lower extremity. The amount of pain and degree of loss of sensation in these extremities vary greatly. Occasionally, apparently normal reflex reactions and vibratory and position sense may be present; usually they are absent. The Wassermann tests on blood and cerebrospinal fluid have been found positive in about only one-third of the patients. The most characteristic findings are roentgenographic changes out of proportion to the severity of the patients' complaints of pain.

The literature on this subject describes the various methods of conservative and surgical treatment of joints of the spine and lower extremity. The advantages and complications of arthrodesis, particularly of the knee, the most commonly involved joint, are well covered. Spine fusion is mentioned in the literature several times as a treatment of unstable and symptomatic degeneration of the spine; however, specific references [2,4] to only three patients treated thus could be found. Steindler in his study of sixty-four cases of Charcot disease included eight patients

with Charcot disease of the spine, one of whom was treated by Hibbs fusion with a good result and arrest of the disease process. Use of a brace was discontinued. In the series of sixty-nine patients reported by Key [2], two patients were treated by spine fusion, one by the Albee and the other by the Hibbs technique. Each had a favorable result, freedom from pain, and arrest of the destructive process. These three patients are the only ones specifically referred to in the literature, although other authors mentioned fusion as a possible treatment.

The purpose of this paper is to describe the case reports and follow-up evaluation of two patients with Charcot disease of the spine treated by fusion.

CASE REPORTS

CASE 1. V. H., a man, fifty-four years old, entered St. Luke's Hospital in June 1941. He stated that for the past three months he had had severe low-back pain radiating to the lower extremities. He had been treated previously at that hospital for a fracture of the right tibia and fibula followed by non-union and osteomyelitis. A below-the-knee amputation of his right leg had been performed twelve years prior to admission. Diagnosis of tabes dorsalis had previously been made. A dilated fixed pupil of the left eye with loss of light reflex was also noted. The right pupil was normal. His knee reflexes were absent. He had been treated with bismuth and arsenicals.

On admission, he stated that his present acute backache had been preceded by several months of mild intermittent back pains which were relieved by rest and aspirin. For three months prior to admission, however, the pains had become severe, radiated down both lower extremities, and were relieved by rest. He had noted marked weakness of both lower extremities for several days, and had been bedridden with pain for three weeks. He also complained of fever, sweats, and recent loss of weight. Examination again revealed unequal pupils with the left pupil dilated and fixed. The knee reflexes and left ankle reflex were absent. Grossly, normal sensations were recorded for the lower extremities.

The preliminary impression was tuberculosis of the spine with impending paraplegia. The history of syphilis was reviewed and, although the blood Wassermann test was negative the cerebrospinal fluid was found to be positive. Roentgenograms of the spine revealed an explosive lesion of the second and third lumbar vertebrae, felt to be typical of Charcot disease (Figs. 1-A and 1-B). Further examination for tuberculosis proved negative.

Because of the unrelenting severity of his complaints, in July 1941, he had a four-segment Hibbs spine fusion extending from the first to the fourth lumbar vertebra with left posterior iliac cancellous bone added. The surgeon noted that the spine was remarkably unstable. The patient remained in bed for approximately four months, then was permitted to walk with a Knight brace. The pain in his back and leg disappeared and full power returned to the lower extremities. Fusion was solid and, with relief of instability, his symptoms disappeared. Right and left lateral roentgenograms made with the patient flexing and extending the spine showed no intervertebral motion between the first and fourth lumbar vertebrae.

Charcot degeneration of the left knee developed, but was controlled by a toe-to-groin brace. The patient has been followed for seventeen years, and has had no recurrence of back or radiating pain. Roentgenograms made recently show solid fusion of the spine without further spread of the destructive process (Figs. 1-C and 1-D). The patient is still able to walk with crutches, a right below-the-knee prosthesis, and left toe-to-groin brace for his unstable left knee. Recent roentgenograms of the spine and knee show increasing instability and destruction of the left knee but the spine has not changed since the fusion became solid seventeen years ago.

Clinical examination revealed absence of the left knee and ankle reflexes, and an Argyll Robertson pupil of the left eye. Cremasteric and superficial abdominal reflexes were absent. The patient had pain and light-touch sensation present in both lower extremities. Vibratory sensation was present but diminished. He complained of some pain in his left knee and right stump on weight-bearing, but he walks adequately with his brace and prosthesis. He has not required a back support since spine fusion became solid. The patient is now seventy-two years old.

CASE 2. G. B., a retired policeman now seventy-nine years old, had a penile chancre forty-five years ago. Generalized rash developed in six weeks and a diagnosis of syphilis was made. Treatment consisted of mercury, arsphenamine, neoarsphenamine, and bismuth. In 1945, the Mazzini test on blood was doubtful but the Wassermann test on cerebrospinal fluid was positive.

This patient gave a thirty-five-year history of "neuritis" described as "shooting low-back spasms and pains." These pains occurred in the mid-scapular area and radiated to the abdomen and down both lower extremities. A diagnosis of tabes dorsalis was made in 1945. At

that time the physical findings included: small, regular pupils which reacted to accommodation but not to light, intact motor function, pinprick and position-sense modalities, but absent knee and ankle reflexes. There was complete loss of vibratory sensation below the level of the pubis.

He was first treated orthopaedically in 1953, when, after six weeks of severe back pain, a

FIG. 1-A

FIG. 1-B

Case 1. Roentgenograms of the lumbar spine showing the extensive fragmentation and destruction present in July 1941.

FIG. 1-C

FIG. 1-D

Roentgenograms of the spine showing a continuous solid fusion with arrest of the destructive process and no further evidence of disintegration.

FIG. 2-A

FIG. 2-B

Case 2. Anteroposterior and lateral roentgenograms of the spine made preoperatively, in 1953, showing destructive and productive changes in the first three lumbar vertebrae and wedging in the twelfth thoracic vertebra.

FIG. 2-C

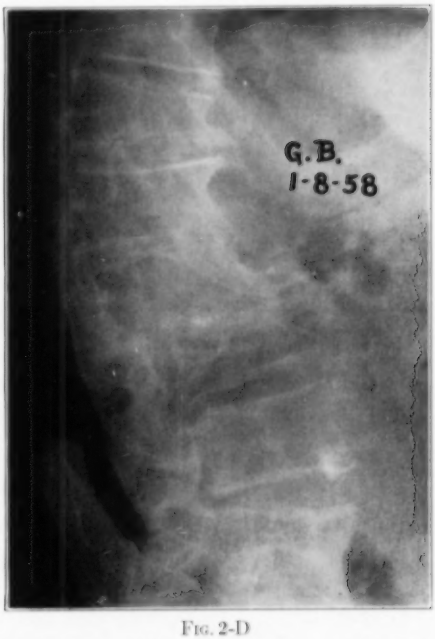

FIG. 2-D

Roentgenograms showing the presence of continuous solid fusion and absence of further destructive changes in the involved area of the lumbar spine.

destructive lesion of the second lumbar vertebra was found (Figs. 2-A and 2-B). This was diagnosed as Charcot disease of the spine with tabes dorsalis. The patient's early symptoms of pain were partially controlled by use of a spine brace, but later the brace offered no relief and roentgenograms showed progression of the disease.

In November 1953, a four-segment Hibbs spine fusion from the first to the fourth lumbar vertebra was performed with left posterior iliac cancellous bone added. He remained in bed approximately one month postoperatively, then walked using a Taylor-Knight brace.

Two months later his progress was complicated by minor trauma which caused a displaced intracapsular fracture of the right femur. This was treated by Smith-Petersen nail fixation; however, because of non-union at six months, a prosthetic hip was inserted.

Postoperatively, urinary retention developed which required transurethral resection of the prostate gland. Microscopic examination of the tissue revealed adenocarcinoma. The patient responded well to all these procedures, but readmission to the hospital was necessary one year later for congestive failure due to coronary arteriosclerosis. He responded again to medical therapy and has remained at home able to walk since that time.

Despite these complications, spine fusion became solid, pain disappeared, and no further evidence of vertebral destruction has appeared anywhere in the spine in the five years following fusion (Figs. 2-C and 2-D). No roentgenograms of the spine in flexion or extension have been made of this patient, but solid fusion can be seen in the other views. He has had no further pelvic-girdle pains, and has not worn his brace since fusion became solid. Clinical examination revealed loss of knee and ankle reflexes, absent vibratory and diminished pain and position sensations from the waist down, and bilateral Argyll Robertson pupils. Otherwise, he has essentially normal motor function of the lower extremities. He still complains of occasional mild "neuritis" pains in the lower extremities, but none in the back. The prosthetic hip has given him minimal pain despite wide excursion of the stem within the femoral shaft as shown on roentgenograms. He walks four or more blocks daily, but uses crutches because of insecurity of the hip.

SUMMARY

Two patients with Charcot disease of the spine who failed to respond to the usual conservative treatment of rest and braces have had relief of back pain after surgical arthrodesis of the involved area. Each of these patients had additional lower-extremity joint lesions which complicated the end result. Spine fusion was solid in both patients, after the usual length of time and postoperative management. Roentgenograms show arrest of the destructive and disintegrating processes of the vertebrae after surgical arthrodesis and solid fusion of the diseased portion. There was no evidence of further destruction in the five and seventeen years, respectively, that these patients were followed.

Not all patients with Charcot disease of the spine require surgery. The authors feel that fusion is indicated in patients with intractable pain, signs of marked instability of the spine, or nerve-root and spinal-cord irritation who have failed to respond to braces. The chance for solid fusion in these patients seems satisfactory.

With solid fusion, one can expect recovery from severe radiating pain, muscle weakness, paraplegia, and cessation of the destructive bone changes. In younger patients with an otherwise good life expectancy, it might be wise to perform this procedure as a prophylactic measure after a definite diagnosis of Charcot disease is made.

The results of only three other spine fusions for Charcot disease of the spine have been reported. In all patients, a satisfactory result was obtained.

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Non-Traumatic Atlanto-Occipital and Atlanto-Axial Dislocation

A Case Report

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Throughout the years since Bell, in 1830, reported subluxation of the atlas on the axis following cervical infection, there have occurred sporadic reports of this relationship of events; Grisel described it one hundred years later. In Bell's patient, subluxation followed erosion of the transverse atlanto-axial ligament as a result of infection due to a pharyngeal ulcer and in Grisel's patient, it followed pharyngitis. Later Watson-Jones reported subluxation due to spontaneous hyperaemia of the atlas and relaxation of the transverse ligament. Stein and associates added that laxity of the joint capsule must also accompany the previously described condition and suggested that effusion into the atlanto-axial joint resulting from hypersensitivity might occur. One must agree with Berkheiser's assumption that this is an inflammatory process of the joint and its periarticular structures and that it may originate either from an ascending lymphangitis or from direct extension. We also agree with Lippmann's view that ligamentous flaccidity is primarily responsible for this condition. However, we can add nothing to the knowledge of the intricate mechanism of the inflammatory process.

The case reported in this paper is unique since dislocation of the atlanto-occipital joints was present in addition to atlanto-axial dislocation mentioned previously. Although much has been written about the forward dislocation of

FIG. 1-A

FIG. 1-B

Fig. 1-A: Lateral roentgenogram of the cervical spine showing subluxation of the atlas in relationship to the axis and occiput.

Fig. 1-B: Open-mouth roentgenogram of the cervical spine showing compressed superior right articular facet of the atlas (arrow).

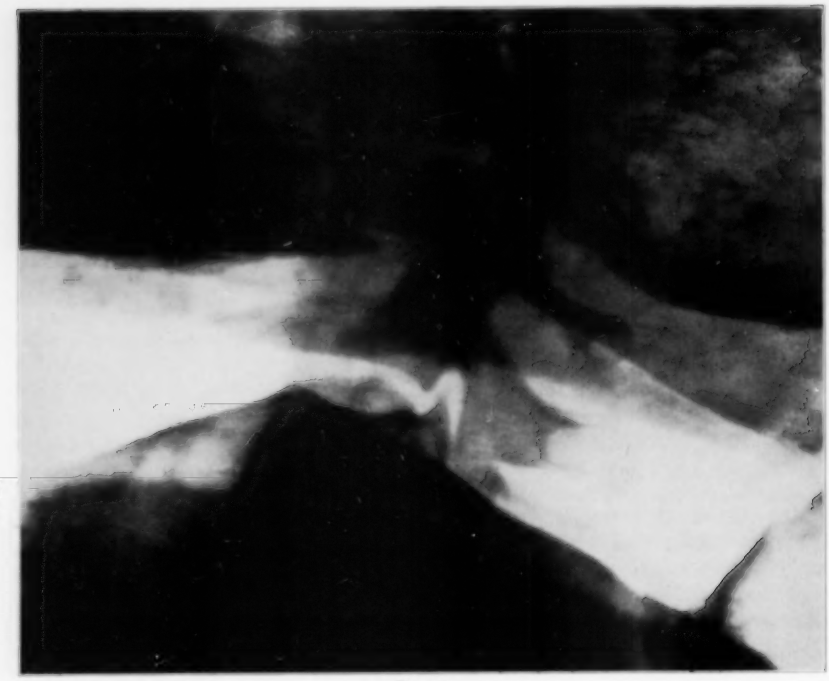

FIG. 2

Roentgenogram of the cervical spine showing maximum reduction of subluxation after wedging of the cast.

the atlas on the axis, there is little written about dislocation of the atlanto-occipital joints. It would seem that changes in these joints occur, to some degree, in patients with severe cases. In this condition the maintenance of erect posture demands some stress on these joints and this patient shows its effect.

B.L.D., a Negro girl, eleven years old, was first seen in the out-patient clinic on April 24, 1956. Her mother said that for the previous four months the child had difficulty of varying severity turning her head to the right. She had also had recurrent sore throat during that time. Recently, the right side of the neck had become stiff and she felt more pain. She had been seen in the out-patient clinic at another hospital and given antibiotics, but relief was only temporary.

On admittance to the hospital, no history of old or recent injury was disclosed after careful investigation. Examination revealed severe spasm and elicited pain of the muscles of the right side of the neck. Some evidence of pharyngitis remained but this was not marked. Temperature was 99 degrees Fahrenheit. Complete blood count was within normal limits except for possible elevation of the white cell count (13,500—polymorphonuclear neutrophils, 74 per cent; lymphocytes, 25 per cent; and basophils, 1 per cent). The erythrocyte sedimentation rate was fifty millimeters (Westegren). The antistreptolysin titer was 500 units. C-reactive protein, Kahn, and Mantoux tests were negative. Roentgenograms of the cervical spine were within normal limits except for slight scoliosis to the left. With cervical traction (halter) and antibiotic therapy the patient improved during the next three weeks and was discharged.

One week later she returned to the clinic with marked tightness of the right posterior cervical muscles and limited motion in rotation and flexion to the left. After readmission to the hospital, functional and open-mouth roentgenograms of the cervical spine showed a definite anterior subluxation of the atlas on the axis. The space between the odontoid process and the anterior arc of the atlas had been increased and widened to the left resulting in asymmetry in the alignment. In addition, the right superior facet of the axis showed an abnormal configuration. Again the child was placed in cervical traction of four pounds for three days and then traction of seven pounds which was maintained for two weeks.

A Calot jacket was then applied and wedged in an attempt to improve the relationship of the occiput, atlas, and axis; it was worn for a period of three months. A cervical brace

FIG. 3-A

Lateral roentgenogram of the cervical spine showing position of the right atlanto-axial joint.

FIG. 3-B

FIG. 3-C

Roentgenograms made in flexion and extension. In Fig. 3-B, note evidence of ligamentous repair.

was then worn for another three months. Roentgenographic re-examination revealed what seemed to be a normal relationship of the occiput and atlas. The atlas, however, had remained dislocated anteriorly on the axis. The brace was removed and since then there has been no recurrence.

At clinical examination two years later (March 25, 1958), the patient held her head

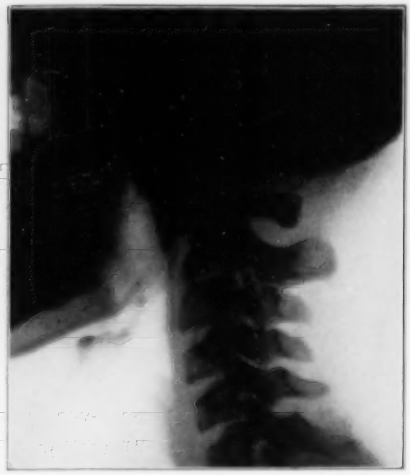

FIG. 4-A

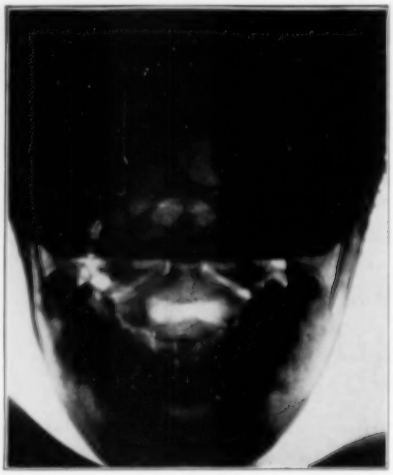

FIG. 4-B

Roentgenograms made at the last examination show the result.

normally in a neutral position. Rotation was accomplished to 40 degrees in both directions, extension to 35 degrees, flexion to 45 degrees, and lateral bending to 45 degrees on both sides.

COMMENT

This patient had not only forward dislocation of the atlas on the axis but also forward dislocation of the atlas in its relationship with the occiput—in effect, a backward dislocation of the occiput on the atlas (Figs. 1-A and 1-B).

Maximum reduction that was obtained can be seen in the roentgenogram (Fig. 2). Follow-up roentgenograms show the relationships of the occiput with the atlas and the atlas with the axis in three functional positions (Figs. 3-A, 3-B, and 3-C).

The relationship of the occurrence of the subluxation with the onset of pharyngitis was established by records, available from the out-patient clinic of another hospital, which indicate that the inflammatory process was at its height two and a half weeks before she came under our observation.

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Congenital Absence of the Odontoid Process of the Axis

Report of a Case

BY E. L. GILLMAN, M.D., LONG BEACH, CALIFORNIA

Prior to this case report, some twenty-one cases of congenital malformation of the dens epistrophei have been described. The first case report appeared in 1933. These anomalies have been classified into three types: total absence of the dens; partial absence (hypoplasia); and failure of fusion of the tip or separate ossicle (os odontoideum). The entire recorded literature was reviewed in excellent fashion by Schiller and Nieda.

CASE REPORT

The patient, a white man forty-two years old, employed by a construction engineering company, was first seen in April 1957. Three days before examination a 200-pound jack dropped six feet from an overhead bridge and struck him on the head. He was wearing a protective metal hat at the time. The blow was so intense that the hat was dented. His head was flexed forward by the impact. A few hours after the injury he began to notice pain in the lower part of the neck.

FIG. 1

The conventional transoral view showing a rudimentary dens.

At examination the patient was not in acute distress. Bell's palsy of the right side of the face, a previous condition, was noted. The cervical spine was normally aligned and there was no muscle spasm. There was tenderness over the spinous processes of the fourth, fifth, sixth, and seventh cervical vertebrae. There was some tenderness over the left paracervical muscles extending down over the trapezius. The neck moved freely. The patient did not complain of distress radiating to the upper extremities. The neurological examination disclosed no abnormality.

Roentgenograms of the cervical spine, made in the conventional transoral view, showed absence of the odontoid process (Fig. 1).

The past history revealed no prior neck distress or injury to the head or neck. The patient was one of seven siblings, all living and well. None of the other members of the family were known to have had neck distress.

FIG. 2

FIG. 3

Fig. 2: Planigram demonstrating the rudimentary dens and the mild subluxation to the right of the second cervical vertebra.

Fig. 3: Lateral planigram showing no tendency to anteroposterior subluxation.

The patient was given conservative physical therapy consisting of heat and massage without traction and was relieved of his symptoms within two weeks. At no time did he complain of distress in the upper part of the neck or at the base of the skull.

At this time anteroposterior and lateral planigrams of the cervical spine demonstrated the absence of the odontoid process with only a faint bulge just to the right of the mid-line to indicate a rudimentary dens (Fig. 2). On the anteroposterior view subluxation of the atlas, five millimeters to the right of the axis, was noted. Early degenerative change with spur formation was found on the left inferior articular surface of the lateral mass of the atlas; there was a suggestion of a similar process on the opposite side. This suggested that the condition was chronic. On the lateral view of the atlas, there was evidence of posterior subluxation of a few millimeters (Fig. 3).

The diagnoses established were: (1) roentgenographic evidence of aplastic odontoid process with instability of the atlanto-axial joint without clinical signs or symptoms; (2) no evidence of recent bone injury of the cervical spine; (3) mild myofascial and ligamentous sprain of the cervical spine.

The patient was again seen in November 1958 for follow-up examination. He had had no further neck distress with the exception of an occasional feeling of tightness in the lower part of his neck interpreted as representing reflex muscle spasm associated with tension. Additional roentgenograms demonstrated continuing asymptomatic subluxations of the atlas on the axis laterally, to the right and left, and posteriorly (Figs. 4, 5, 6, and 7).

DISCUSSION

Another case of congenital aplastic odontoid process of the axis is presented. A blow on the head was followed by symptoms of distress low in the neck; these were mild and not disabling. At no time while under clinical observation did the patient have symptoms referrable to the defective, unstable atlanto-axial joint. Mild asymotomatic lateral subluxation of the joint could be demonstrated roentgenographically without external stress.

A review of the previous cases presented has indicated rarity of the condition. This may be due to the fact that the anomaly is compatible with the ordinary

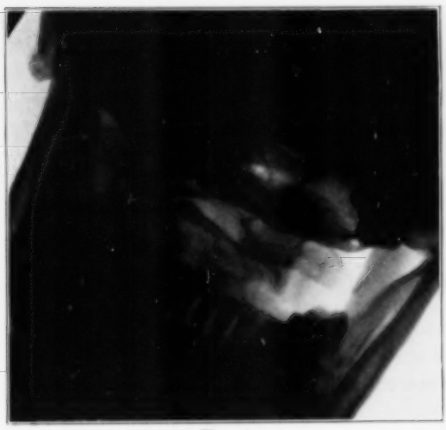

FIG. 4

FIG. 5

Fig. 4: Roentgenogram made two years after the incident. Lateral instability of the atlanto-axial joint is demonstrated when the patient bends to the left.
Fig. 5: Instability is visible with the patient bending to the right.

FIG. 6

FIG. 7

Fig. 6: Lateral roentgenogram in forced flexion.
Fig. 7: Lateral roentgenogram in extension shows slight posterior subluxation of the atlanto-axial joint.

stress and strain of normal movements of the head and neck without distress.

In the twenty-one case histories reported in the literature [1], trauma brought attention to the condition. It is of interest to note that the flexion-extension injury, commonly resulting from automobile accidents, was a precipitating circumstance in only one patient. In fifteen patients, symptoms were characteristic of a derangement of the upper portion of the cervical spine; but in six patients as in the case herein presented, symptoms referable to the upper part of the neck were absent.

The anatomical variants found in the reported cases were: total absence of the dens in fourteen patients; agenesis or hypoplasia of the odontoid process in three; and os odontoideum in four. Dislocation of the atlas on the axis was noted

in twelve patients, more often anterior rather than lateral or posterior. In one of the reported cases, there was subluxation. Excessive mobility of the atlas and the axis was reported in three patients.

Other associated developmental anomalies included: regional malformations resembling Klippel-Feil syndrome in two patients; platybasia in one patient associated with the Klippel-Feil deformity; and in one patient, thickening of the arch of the atlas.

In the twenty-one patients reported, there were three deaths. One, a fourteen-year-old girl, died with signs of hemiplegia due to a rongeured fragment of the atlas being accidentally driven into the medulla during the fusion operation. In the second patient, pronounced platybasia, malformed occipital lobes of the brain, and Klippel-Feil deformity with fusion of the bodies of the first and second cervical vertebrae were found at autopsy. Death was due to tonsillar herniation into the foramen magnum. In the third patient, death occurred two days after roentgenographic examination. The patient had complained of headache and vertigo for one month with posterior dislocation of the atlas. An autopsy was not performed. In other case reports of patients with simple aplastic dens formation no deaths were reported.

Various forms of therapy have been reported including traction, cast immobilization, or a collar; some patients had no treatment. Fusion was recommended to ten patients but performed in only three; there was one death. The majority of the reported patients refused the risk of fusion which to them seemed to outweigh the clinical severity of symptoms.

CONCLUSION

Instability of the atlanto-axial joint, secondary to absent or aplastic odontoid process not associated with other malformations, in itself presents a less grave hazard to health or life than one would expect. The abnormally mobile joint does not necessarily give rise to symptoms of the upper part of the cervical spine. Rather, due to the absence of the dens, preternatural mobility of the joint is entirely compatible with the safety of the medulla. On the contrary, should such abnormal mobility occur with an intact dens, medullary damage or death, or both, would most certainly ensue.

It is then seen that the defective unstable joint in such cases should not be, in itself, the sole criterion for fusion of the joint, a highly formidable procedure.

In the case report presented, the aplastic dens was wholly asymptomatic. If roentgenograms had not been made of the cervical spine, the anomaly might never have been detected. The negative past history and the follow-up examination, one and one half years later, demonstrated that no serious instability of the atlanto-axial joint existed. The mild lateral and posterior subluxations no doubt occurred with every motion of the head.

Since there were no symptoms referrable to the condition, no other therapy was considered or recommended other than the usual precautions against serious trauma to the head, such as might occur in diving, tumbling, or wrestling.

SUMMARY

Congenital anomalies leading to a defective unstable atlanto-axial joint are rare. The resultant joint instability appears to present less serious clinical problems than the anatomical possibility suggests. Other than prophylactic indications are necessary before surgical fusion of the joint is performed.

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Ewing's Sarcoma and Reticulum-Cell Sarcoma of Bone

With Special Reference to the Histochemical Demonstration of Glycogen as an Aid to Differential Diagnosis

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Primary reticulum-cell sarcoma of bone was first distinguished from Ewing's sarcoma by Parker and Jackson who pointed out the different clinical and pathological features of the two tumors. Ewing [5] accepted their criteria for the new tumor entity when he reviewed and revised the classification of bone tumors of the Bone Sarcoma Registry. Many cases have since been reported [3,7,12,14,15,20,26,28,33,34] some of them in large series [6,9,13,16,24,27,35,36], the largest being those of the Memorial Hospital (forty-four cases)[6], the Mayo Clinic (forty-nine cases)[13], and the Rizzoli Institute (thirty cases)[24].

Although the number of well documented cases seems to reinforce the concept of the existence of primary reticulum-cell sarcoma of bone, a considerable number of authors still feel that it is impossible to separate this entity from Ewing's sarcoma, pathologically and clinically [1,2,10,17,21,22,26]. Some, following Oberling's hypothesis, interpret the tumor as showing one stage of differentation of reticular cells from a more undifferentiated type of cell [8,11]. Some authors [6,18,19] who consider primary reticulum-cell sarcoma of bone a distinct entity emphasize its close histological similarity to Ewing's sarcoma, and admit that "in fact, occasionally the distinction cannot be made with certainty" [6]. In one case at least, the diagnosis could not be established until autopsy [19].

It is clear, therefore, that thorough histopathological study is fundamentally important in segregating the two entities on the basis of clear and definite criteria. The distinction has more than academic importance, since the more favorable clinical course of reticulum-cell sarcoma compared with that of Ewing's sarcoma and other sarcomata of bone is generally appreciated. Reports of five-year survivals in fifteen of thirty-two patients and in eleven of twenty-five patients are available [6,19].

The clinical and pathological features of many of the cases upon which this report is based have previously been described [27,36]. The histological studies reported were based on ordinary staining techniques, supplemented by Del Rio Hortega's silver-impregnation technique, which has proved most helpful despite some opinions to the contrary [16,19]. The present study, reported in a preliminary way in 1953 [29,30], resulted from a systematic histochemical study of the occurrence of glycogen in normal and pathological specimens of skeletal tissue. The presence of glycogen granules in the cells of Ewing's sarcoma and their absence in primary reticulum-cell sarcoma is the main finding which will be demonstrated. This provides a method of differential diagnosis which is both useful and easy, when properly fixed specimens are used.

MATERIALS AND METHODS

Fifty-one cases of Ewing's sarcoma, thirty-one of reticulum-cell sarcoma of bone of which nineteen were primary, and five cases of reticulum-cell sarcoma of the soft tissue of the extremities were studied. In addition to ordinary stains,

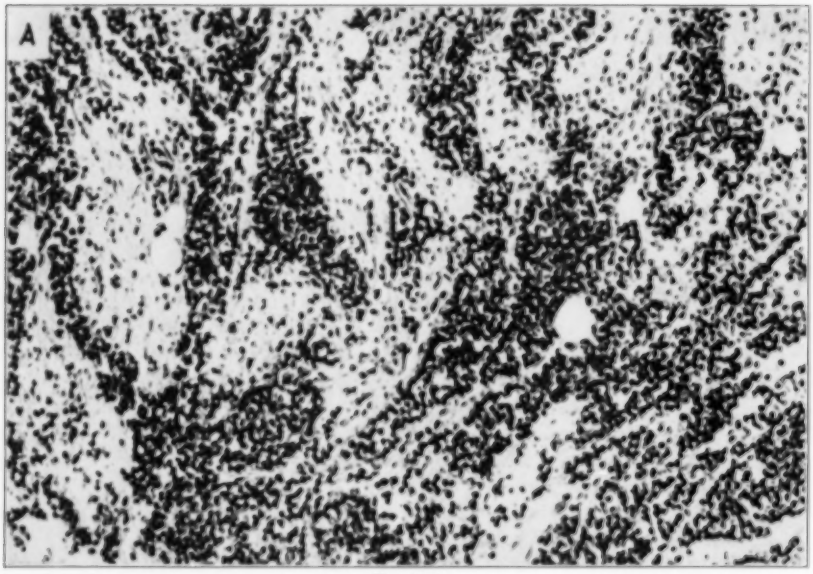

FIG. 1-A

Photomicrograph (× 160) of tumor cells of Ewing's sarcoma. The cells are uniform and are disposed in lobules and strands, separated by fibrous septa.

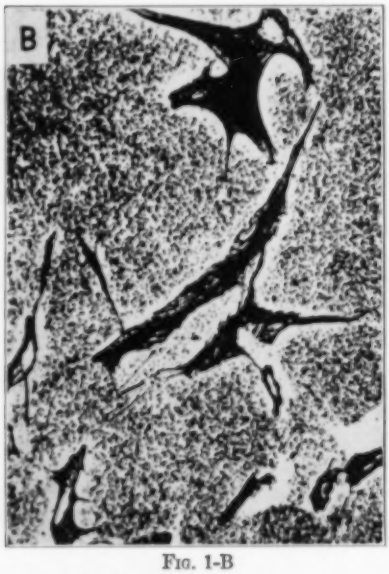

FIG. 1-B

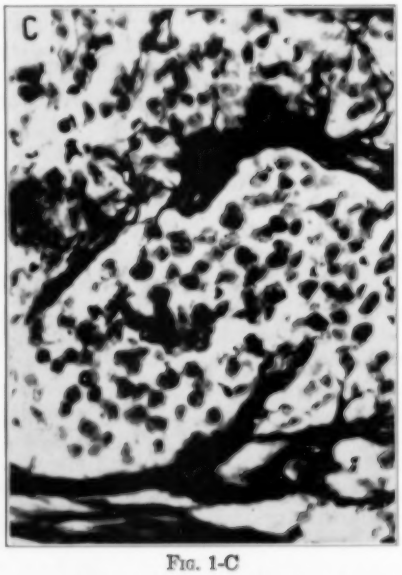

FIG. 1-C

Figs. 1-B (× 68) and 1-C (× 275): Reticulum stains at different magnifications showing the reticular fibers circumscribing large lobules of tumor cells with some fibrils encircling individual cells (Del Rio Hortega's technique).

Del Rio Hortega's and Gomori's methods for reticular fibers were used on these cases. Among the above cases, eight Ewing's sarcomata, nine reticulum-cell sarcomata of bone, of which four were primary in bone and five were disseminated lesions, and two reticulum-cell sarcomata of soft tissue were studied by histo-

chemical methods which will be described. In addition, eight myelomata and a number of other lesions involving hyperplasia of the reticulo-endothelial elements of the marrow, for example, eosinophilic or histiocytic granuloma, and malignant lymphomata (Hodgkin's disease and lymphosarcoma) were likewise studied.

The specimens were fixed in 10 per cent formalin, in 80 per cent alcohol at 5 degrees centigrade, and in Rossman's fluid. The latter two fixatives have served to demonstrate glycogen [32] almost as well as the more difficult freeze-drying method of Altmann-Gersh. Formalin fixation does not always preserve glycogen; this was shown in the older material from Ewing's sarcoma.

Glycogen and mucopolysaccharides were stained by McManus or Hotchkiss techniques, controlled by ptyalin digestion at 37 degrees centigrade for two to three hours or by exposure to takadiastase at room temperature for half an hour or one hour. Alkaline phosphatase was demonstrated by Gomori's technique using different incubation periods: ten minutes, thirty minutes, three hours, and twenty-four hours at pH 9.2. Acid mucopolysaccharides were stained by the Lison-Sylvén method (0.5 per cent toluidine blue) and by Hale's colloidal iron method [30].

RESULTS

Ewing's Sarcoma

The purpose of this paper is not to present in detail the clinical or pathological aspects of Ewing's sarcoma. New histochemical findings and those details of histology and clinical course necessary for establishing diagnostic criteria will be described. Of the fifty-one patients with Ewing's sarcoma seen, forty-three died within two years of onset. One patient survived three years and another was well after four years. The remaining six patients were followed less than one year, and, at the time of writing, four of them had osseous or pulmonary metastasis.

Material for histological study often showed necrosis; such imperfectly preserved material could often be confused with lymphosarcoma or reticulum-cell sarcoma. For this reason, only perfectly preserved areas of tumor yielded optimal histological information. Diagnosis has been made from aspiration biopsy in the majority of cases [23,31] and often confirmed by pathological examination of the amputated specimen or of material obtained by surgical biopsy.

The tumor consisted of strands or sheets of cells, fairly regular in size and shape, separated by wide fibrous septa (Fig. 1-A). The perithelial arrangement of cells may have been due to perithelial proliferation, or, more often, to necrosis of the tumor tissue which was at some distance from the blood vessels. The tumor cells in paraffin sections usually showed ill defined and scanty cytoplasm, often vacuolar or syncytial. The syncytial masses were not visible on frozen sections. The nuclei were round or oval, about two or three times the size of a lymphocytic nucleus, with a small amount of finely divided chromatin and indistinct nucleoli. Few typical or atypical mitotic figures were seen. There were abundant vessels, but little collagenous stroma. In zones of necrobiosis, the nuclei often were small and pyknotic and the cytoplasm scanty or abundant. The cell walls were often clearly visible. The morphology of these changed cells appeared to correspond to the original description by Ewing [4]. Sometimes the cellular groups surrounded small necrotic foci yielding formations which resembled the rosettes of neuroblastoma.

Del Rio Hortega's silver-impregnation technique (Figs. 1-B and 1-C) showed a lobular distribution of the reticular fibers circumscribing large areas of tumor cells into which few if any fibrils penetrated. The tumor cells took no stain by the specific technique for reticulo-endothelial elements which are found almost exclusively among the reticular and collagen fibers surrounding the tumor lobules [27]. Specimens, fixed in 80 per cent alcohol or Rossman's fluid, from eight

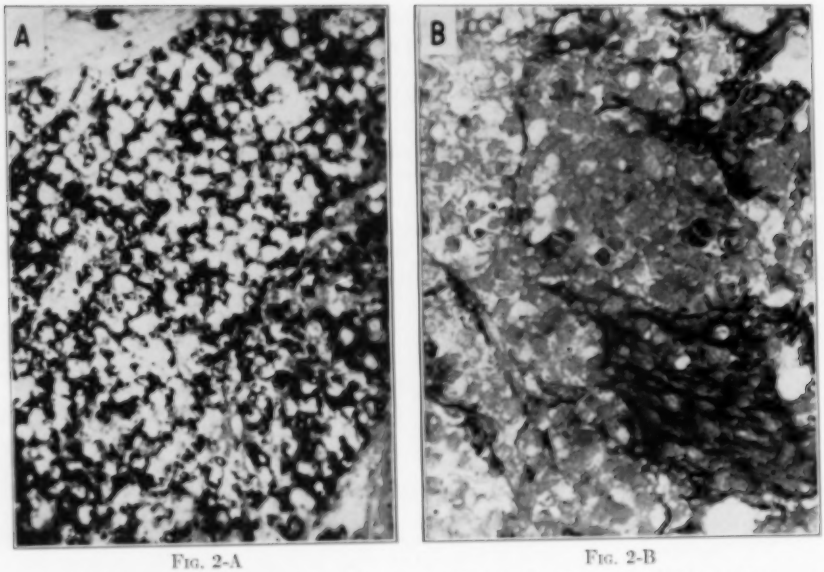

FIG. 2-A FIG. 2-B

Fig. 2-A: Glycogen stains of same specimen as in Figs. 1-A, 1-B, and 1-C. The nuclei appear as blank disks since no counterstain has been used. The glycogen in the cytoplasm stains darkly in granules (80 per cent alcohol fixation, McManus stain, × 480).

Fig. 2-B: Control specimen after treatment with ptyalin for three hours at 37 degrees centigrade. The glycogen granules have disappeared (× 480).

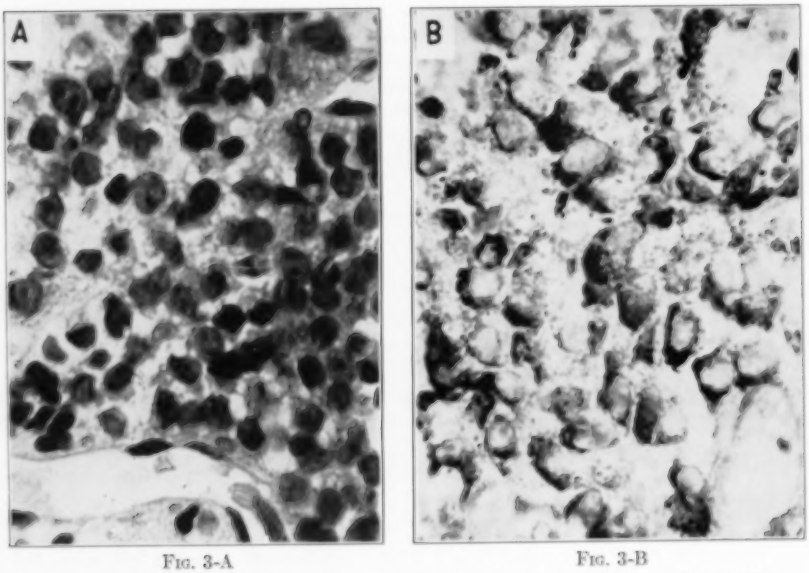

FIG. 3-A FIG. 3-B

Fig. 3-A: Photomicrograph of specimen of Ewing's sarcoma, obtained by aspiration biopsy, stained with hematoxylin and eosin after fixation in 80 per cent alcohol. The cytoplasm is invisible by this technique (× 675).

Fig. 3-B: Same fixation stained by means of the McManus method without nuclear counterstain. The nuclei are unstained and the cytoplasm is now well outlined due to its abundance in glycogen granules (× 675).

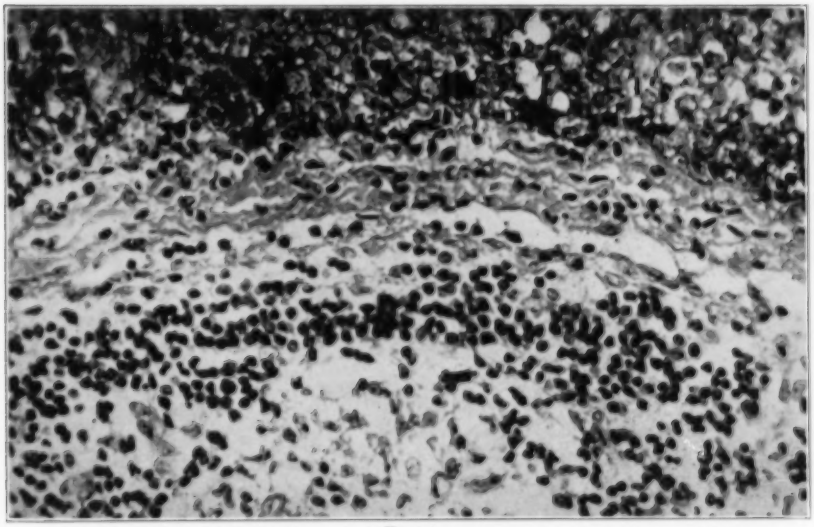

FIG. 4

Photomicrograph of metastasis to a lymph gland of Ewing's sarcoma. The upper portion shows abundant glycogen granules although the material is formalin fixed. The lower portion shows no glycogen granules in the lymphoid or reticulo-endothelial elements of the node (McManus stain, hematoxylin counterstain, × 500).

patients with Ewing's tumor, were stained by McManus and Hotchkiss techniques and showed abundant glycogen in granular form filling the cytoplasm (Figs. 2-A through 3-B). The granules varied from fine to coarse. Most of the tumor cells contained granules regularly and uniformly, but some areas, apart from the necrotic ones, may have existed in which glycogen was lacking. Previous digestion by ptyalin or takadiastase caused the periodic acid Schiff positive granule to disappear, thus confirming that they were indeed glycogen granules. In one case of metastasis to the lymph node, the periodic acid Schiff positive granules were absent in the lymphoid and reticular elements of the node, but were present in the tumor cells (Fig. 4).

Fixation with 80 per cent alcohol, while just as satisfactory as Rossman's fluid, had the advantage of preserving alkaline phosphatase. Formalin fixed material preserved for years has given positive results for glycogen in only half the cases studied. It has long been known that glycogen is inconstantly preserved by formalin.

The tumor cells showed no metachromasia and no Hale positive substances. Alkaline phosphatase was present only in the vessel walls.

Reticulum-Cell Sarcoma of Bone

Histological material from nineteen primary reticulum-cell sarcomata of bone and from twelve reticulum-cell sarcomata of soft tissue with osseous metastases was studied. The clinical and roentgenographic characteristic of these cases[36] differed only slightly from those of other authors. Six of the nineteen patients have survived for more than five years, while three of these are living after ten years.

The tumor consisted of cells identical in morphology to reticulum cells seen in reticulum-cell sarcoma of soft tissue. The nuclei were larger than those in Ewing's sarcoma, were poor in chromatin, and were oval, lobulated, or reniform in shape. Occasionally more than one nucleus was observed. The nucleoli, frequently multiple, were generally large and prominent. The cytoplasm was slightly

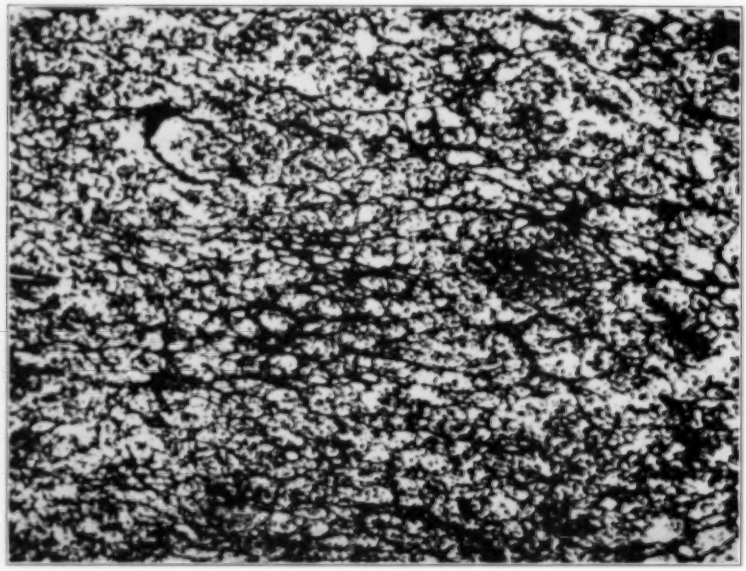

FIG. 5

Primary reticulum-cell sarcoma of bone stained with Del Rio Hortega's silver-impregnation technique. Numerous reticulin fibers, forming a dense network, surround individual cells or small groups of cells (× 125).

basophilic and often clearly outlined. Among the tumor cells, a few smaller cells resembling lymphocytes could frequently be seen (Figs. 6-A and 6-B). Del Rio Hortega's technique showed a rich reticular framework and a characteristic distribution of fibrils surrounding individual cells or groups of cells (Fig. 5).

The microscopic aspect of metastatic reticulum-cell sarcoma with the primary lesion in soft tissue was identical with primary reticulum-cell sarcoma of bone, either when the metastatic lesion was a single one or, as was more common, when multiple metastases were present. On some occasions the disseminated bone lesions were the only lesions discovered. In cases of this type, which should be classified as reticulosarcomatosis of bone, autopsy may be necessary to determine whether they were metastatic or multicentric primary tumors. This point may underline the need for thorough clinical and roentgenographic investigation of what appears to be reticulum-cell sarcoma of bone.

In none of the nine cases of reticulum-cell sarcoma (four primary and five secondary) was glycogen found in the cells of the tumor, despite adequate fixation in Rossman's fluid or 80 per cent alcohol. The older material which was fixed in formalin also lacked glycogen granules. The tumor cells did not have metachromasia, Hale positive substances, or alkaline phosphatase activity. The two cases of reticulum-cell sarcoma of soft tissue and the series of malignant lymphomata studied for comparison lacked glycogen, except for the polynuclear leukocytes present in Hodgkin's granuloma.

DISCUSSION

The pathological material on which this report is based is similar to that of other authors and is convincing evidence that primary reticulum-cell sarcoma of bone may be separated from Ewing's sarcoma as a distinct and specific entity with characteristic pathological features. Certain cases may be distinguished by clinical and roentgenographic examination, but definite diagnosis must always rest on histopathological findings. Proper differentiation between the two entities is imperative because of the vastly better prognosis of reticulum-cell sarcoma.

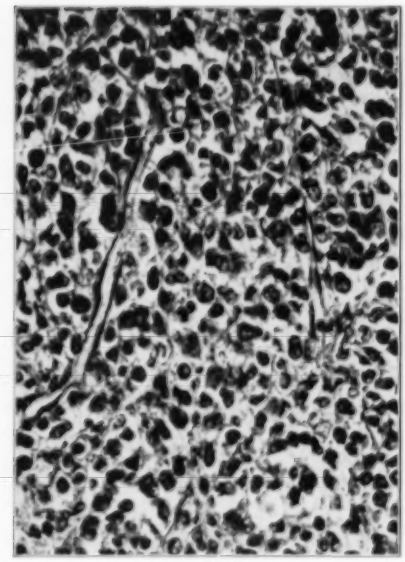

FIG. 6-A

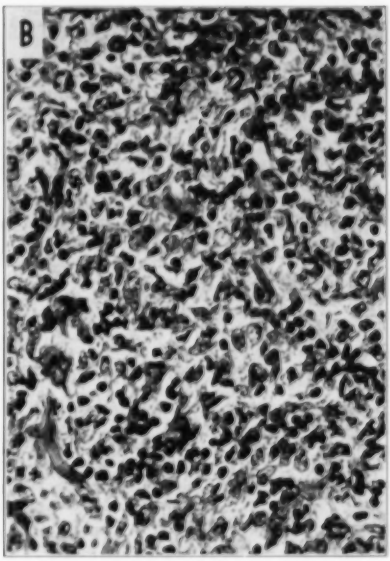

FIG. 6-B

Two cases of primary reticulum-cell sarcoma of bone stained by means of the McManus method after fixation in Rossman's fluid. Glycogen is absent in the tumor cells (× 275).

The histological differentiation of these two tumors is not difficult in the majority of cases; but, in some, it has proved difficult [6,19]. This difficulty may be due to lack of sufficient study with special stains, particularly those for reticulin, or to degenerative change in the tissue from necrosis or improper fixation. Difficulties are particularly prone to occur in material obtained by aspiration biopsy where the specimen may be very small. The present work demonstrated clearly that abundant granules of glycogen are present in the tumor cells of Ewing's sarcoma and are absent in those of reticulum-cell sarcoma, provided the specimens are properly fixed and stained. It showed that Rossman's fluid or 80 per cent alcohol are superior to formalin as fixatives for this purpose, since formalin inconstantly preserves glycogen. The periodic acid Schiff stain in McManus' or Hotchkiss's modification has been satisfactory. There was no exception to this consistent differentiation of the two tumors by glycogen staining in the eight cases of Ewing's sarcoma and the nine cases of reticulum-cell sarcoma of bone which had been fixed and stained by the methods described. In older material, fixed in formalin, glycogen was found in about half the cases of Ewing's sarcoma, but in none of those of reticulum-cell sarcoma. This histochemical segregation of the tumors is simple and efficient and should constitute a helpful addition to the methods of differential diagnosis.

It is unusual for any one laboratory to examine large numbers of these tumors; it is hoped that confirmation of these results by others will be forthcoming. There are few bone tumors that can present diagnostic difficulties due to an abundance of glycogen in their tumor cells. In undifferentiated areas of osteogenic sarcoma, when the cells are uniform, they may contain glycogen. In these cases, the intense alkaline phosphatase activity of the tumor cell permits differentiation from Ewing's sarcoma in which such activity is absent. The histological differential diagnosis of neuroblastoma may also present difficulties. Although the few cases studied by formalin fixed material lack glycogen, these results are not considered conclusive.

SUMMARY

1. Primary reticulum-cell sarcoma of bone is an entity which may be differentiated from Ewing's sarcoma, histologically, with the aid of ordinary and special staining methods. The differentiation is important because of the different prognosis of each tumor.

2. The histochemical demonstration of glycogen in tumor cells of Ewing's sarcoma and its absence in reticulum-cell sarcoma of bone proved to be an easy, efficient method of differential diagnosis.

3. Appropriate fixatives and stains must be used to achieve uniform results.

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Osteoid Osteoma

A Fifteen-Year Follow-up of an Untreated Patient

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From the time of its original description as a separate disease entity, osteoid osteoma has been considered to be a surgically curable disease. It is understandable, therefore, that most of the reported cases are those in which the lesions have been surgically excised soon after their detection. Consequently, our knowledge of the condition is greatest in regard to its clinical, roentgenographic, and pathological manifestations and leaves much to be desired concerning its natural course, since this has usually been altered by operative intervention. It may be assumed that more complete knowledge of the course of the untreated disease may be contributory to establishing its exact nature, especially as to whether the lesions are neoplastic or inflammatory, which to date has not been definitely determined.

Six cases have been reported in which untreated osteoid osteomata have been observed from the painful phase until the patient was relatively symptom-free. The first of these cases [5], reported in 1947, was a lesion in the tibia which, after seven years, was no longer painful. After twenty-four years the nidus was sclerotic and no longer could be distinguished as such. In the second case [3], reported in 1948, the lesion was located in the patella, and healed spontaneously two years after the onset of symptoms. In the third case [2], reported in 1951, the patient had a lesion in a metacarpal bone, which healed spontaneously after two years. The last three cases [4] were reported in 1956, and all three patients had lesions involving the spinal column. The point tenderness and roentgenographic evidence of a nidus disappeared in eight, six, and four years, respectively. The only roentgenographic residua were hypertrophic changes in the region of the adjacent articular facets and sclerosis at the site of the nidus in each of the cases. It is the purpose of this paper to present one other case of untreated osteoid osteoma which was encountered at the Mayo Clinic in 1943 and again in 1958.

A twenty-three-year-old man was seen on August 10, 1943. The chief complaint was a deep, boring-type pain of diffuse distribution in the right thigh and low in the back of five years' duration. The pain was more severe at night and was frequently so severe that it disturbed the patient's sleep. He found that the pain was partially controlled by acetylsalicylic acid (aspirin), but was unaffected by external treatment to the extremity. A roentgenogram of the upper portion of the right femur (Fig. 1, left) revealed a fusiform thickening of the cortex in the subtrochanteric region in the center of which was a nidus one centimeter in diameter. The lesion was considered to be either an osteoid osteoma or osteomyelitis, and surgical treatment was recommended. The patient agreed to return for the operation at his earliest convenience. His next visit to the clinic was on August 14, 1958. The history indicated that the pain in the right thigh and in the back had persisted for the entire fifteen-year interim, but that it had been diminishing progressively and at the time of his second visit he was almost symptom-free. A roentgenogram of the upper part of the right femur (Fig. 1, right) showed little change in the appearance of the lesion. The degree of involvement was unchanged, but the nidus appeared somewhat less radiolucent than it had fifteen years before. Since there was no point tenderness over the lesion and the patient was almost symptom-free, no definitive therapy was recommended and the patient was dismissed. After reviewing the history and roentgenograms it was agreed the the lesion was an osteoid osteoma.

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FIG. 1

Roentgenograms of the upper part of the right femur. Left: made in August 1943; right: made in August 1958.

COMMENT

Our knowledge of the natural course of untreated osteoid osteoma in a few cases would indicate that the time from the onset of the active phase of the lesion to the stage of quiescence is unpredictable. This period has varied from two years, in two reported cases, to a total of twenty years in the case that we have followed. Review of the serial roentgenograms of the reported cases suggests that the nidus, as the lesion heals, becomes less radiolucent, but that the region of cortical reaction around the nidus does not resolve.

Since the lesion regressed spontaneously in all of the reported cases, and almost certainly does so in all untreated cases, one might question, as has been emphasized by Jaffe, the theory that the lesion is by nature a true neoplasm. The self-limiting characteristics of the condition would tend to place it in the category of an inflammatory lesion. The microscopic picture is not, however, one of infection. In view of our present knowledge, it is not possible to place the disease in any specific category.

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Osteoblastoma of the Scapula

A Case Report

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It has become evident in recent years that there is a neoplasm of bone containing osteoid which resembles osteoid osteoma but is a much larger lesion. It is sometimes so cellular that osteogenic sarcoma is suspected. Yet, it is benign. Such growths have been called osteogenic fibroma by Lichtenstein. He described them as benign tumor-like processes in bone composed of osteoid and calcified atypical bone in a bed of highly vascular osteoblastic tissue. Although histologically like osteoid osteoma, these lesions erode bone extensively and appear much more aggressive without being malignant.

FIG. 1-A

FIG. 1-B

Fig. 1-A: Postero-anterior roentgenogram of the left scapula made immediately after admission to the hospital, January 7, 1952. Note increased density and enlargement as well as globular shape of the infraspinous part of the scapula, with rounding of the vertebral and lateral borders.

Fig. 1-B: Anteroposterior tangential roentgenogram of the left scapula made January 7, 1952. Note expansion due to thickening of the infraspinous part of the scapula along with increased density and flattened globular shape.

The following case was encountered in 1952 before there was general recognition of the nature of the tumor. It is being reported because of its rarity and because it illustrates the problems involved in recognition and treatment.

W. S., a ten-year-old girl, gave a history of an injury to the left scapula six months prior to admission to the hospital. A few weeks after the injury pain in the region was noted and a mass appeared which grew in size. On physical examination the mass measured

about six by four centimeters and was smooth, rounded, and somewhat tender. It occupied the infraspinous portion of the scapula. There was no restriction of motion, no lymphadenopathy, and no other positive findings.

Laboratory studies including blood count, urinalysis, blood calcium, phosphorus, and alkaline phosphatase were within normal limits.

Roentgenograms made on January 1, 1952 (Figs. 1-A and 1-B), showed bone destruction in the lower two thirds of the left scapula. There was expansion of the bone. The cortex was thinned over the medial posterior part. There was cortical thickening of the lateral border and anterior surface of the scapula. A suggestion of cortical breakthrough was noted posteriorly. The roentgenographic diagnosis was a lytic bone tumor, possibly malignant. Skeletal survey roentgenograms of long bones, skull, chest, and ribs were negative.

A biopsy specimen taken on January 10, 1952 (Fig. 1-D), showed reddish-brown, soft tumor tissue breaking through the cortex of the scapula. The pathological study revealed a highly cellular, osteogenic neoplasm which had destroyed and replaced most of the normal bone. The tumor was composed of numerous large, irregularly shaped, darkly staining cells arranged about numerous small trabeculae of poorly formed bone, calcified cartilage, or osteoid tissue. Many multinucleated tumor cells of bizarre shape were present. Mitoses were numerous. In view of the bone destruction and of the mitoses, low-grade osteogenic sarcoma was suspected.

Because of doubt as to the diagnosis, Dr. Jaffe saw the slides in consultation. Although at that time he had not yet formulated his concept of osteoblastoma by that name, he recognized the lesion as a rare osteoid producing osteoblastic tumor such as he had described in a metacarpal bone. He felt that it was almost certainly benign.

Definitive operation was performed on January 28, 1952, by excision of the infraspinous part of the left scapula. The infraspinatus, teres major, and teres minor muscles were excised with the lesion. The other scapular muscles were separated from the bone extraperiosteally with no difficulty. The entire tumor was contained in the resected mass.

The specimen measured fourteen by eight by four centimeters. The deep surface of the bone was expanded into a convexity instead of being concave. The infraspinatus muscle was closely attached to the dorsal surface of the lesion. The tumor on section (Fig. 1-C) measured six by five centimeters and was oval. It was surrounded by a margin of sclerotic bone. It extended to the vertebral border but did not perforate it. There was a margin of bone two centimeters thick superiorly and laterally. The center of the tumor was soft and crumbly, but not vascular. Several areas were hemorrhagic and necrotic. The only perforation by the tumor had occurred dorsally into the infraspinatus. Microscopically the tumor was as described in the biopsy report. In spite of Dr. Jaffe's opinion, there still remained some doubt that the lesion might be low-grade osteogenic sarcoma of the scapula.

The postoperative course was uneventful. The patient has been followed for over six years and has remained entirely well. Repeated roentgenographic studies of the chest showed

FIG. 1-C

Vertical coronal section of the resected specimen opened out in book fashion.

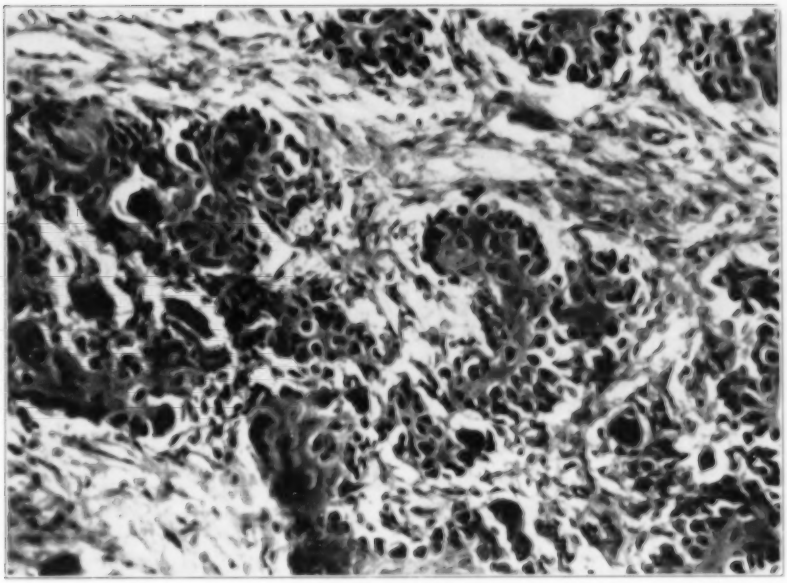

FIG. 1-D

Microscopic section (× 125). Note clusters of osteoblastic cells surrounding fragments and strands of osteoid tissue. The cells are pleomorphic, in a loose fibrovascular stroma in between areas of osteoid deposit, but not anaplastic. Occasional multinuclear osteoclastic cells are present.

no evidence of pathological changes. The function of the left shoulder has approximated the normal in motion, strength, and utility. There have been no complaints nor signs of recurrence. Some periosteal regeneration of irregular plaques of bone was noted in roentgenographic study of the former scapular bed.

Although the nature of the tumor originally was not clear, it seems evident now that it falls into the category of osteoblastoma [4,5]. Local resection was elected as the treatment of choice rather than scapulectomy or interscapulothoracic amputation. Fortunately, the lesion proved to be resectable, and the subsequent benign clinical course and apparent cure after six years of follow-up have justified the treatment.

Since 1952, a number of reports of similar tumors have appeared in the literature under various titles. Giannestras and Diamond in the most recent and most complete review of the literature analyzed all the preceding cases of other authors as well as their own. They described the clinical, roentgenographic, and therapeutic features in detail and pointed out that the cases reported by Jaffe and Mayer, Golding and Sissons, Kirkpatrick and Murray, Dahlin and Johnson, and Jaffe all fell into the same category. Although some reported cases have been called osteoid osteoma, osteogenic fibroma, or giant osteoid osteoma, Jaffe's term *benign osteoblastoma* has been accepted by Lichtenstein and by Giannestras and Diamond.

In most of the reported cases, the tumors had suggested malignancy by their early clinical evolution but later proved to be benign. They were characterized, not by the severe pain of the usual osteoid osteoma, but by growth to a much larger size with progressive compression of adjacent bone and soft tissues. The lesion does not have either a nidus or the typical sclerosis which surrounds the ordinary osteoid osteoma so that the roentgenographic appearance of the two lesions is entirely different. The osteoblastoma group has followed a benign but aggressive course producing osteoid "yet falling short of osteogenic sarcoma" [8].

The surgical approach should be influenced by the need to remove an aggressive lesion, without amputation or mutilating resection. Even partial resection has proved relatively successful in areas such as the spine where complete removal was impossible.

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A Metatarsus Varus Splint for the Pre-Walker

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The maintenance of correction of varus of the fore part of the foot in the pre-walker may present a problem. Some of these cases have a tendency to recur. All affected feet should be held with the fore part of the foot in valgus for some time after the cast has been removed. The duration of this period of immobilization should vary with the severity of the original deformity and the difficulty encountered in correction. The foot is often too small to be held properly in a shoe; a bivalved cast soon crumbles and permits the hind part of the foot to turn. What is required is a device which is quickly and conveniently applied, which can be removed for a few days at a time to see if the correction is being held, and which can be easily modified to increase or decrease the amount of valgus in which the fore part of the foot is held.

A brace which had been used successfully in the treatment of older patients with metatarsus varus [1] has been modified to hold these small feet and to permit accurate changes in the degree of correction. The splint can be made easily in a few moments by the physician at the treatment table with stock aluminum strip.

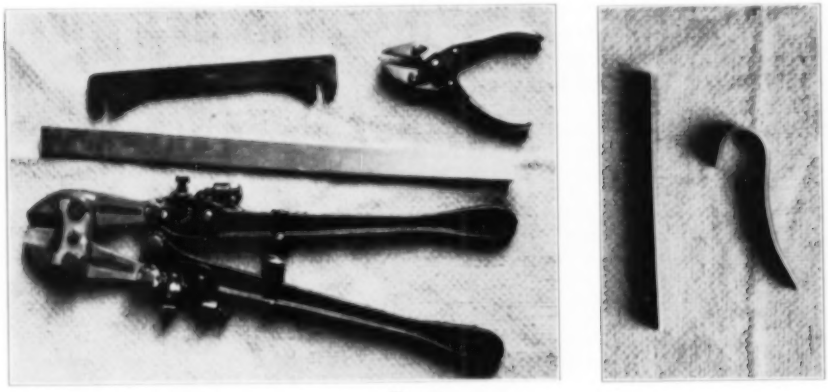

FIG. 1

FIG. 2

The material is readily available and when covered by moleskin adhesive has not caused any irritation of the skin. The strips are cut to length, bent to fit the foot, covered with moleskin strips, and taped to the heel and fore part of the foot. A soft flannel bandage serves to keep the adhesive clean and on the leg. There has been no problem from skin irritation. It is rather strange but quite convenient that these feet stand up to properly applied moleskin or even plain adhesive so well. Even the tape-on Denis Browne splint rarely causes any skin problem. This metatarsus varus splint is designed to hold the heel snugly and to control the fore part of the foot; it may be easily and quickly applied.

Stiff aluminum strip one-half of an inch to three-quarters of an inch wide and one-sixteenth of an inch thick is used. This material can be bent with pliers and small bending irons and yet hold its shape (Fig. 1). It is cut into six to seven-inch lengths depending on the size of the foot. The splint is then bent to fit the heel. This bend is given a slight twist to conform to the slope of the heel. The other end of the splint is bent out gently to hold the metatarsal region in the corrected position (Fig. 1).

Figure 2 shows the splints on the feet after plaster correction of the varus deformity. Usually they can be left on for two weeks at a time if the skin has been prepared with tincture of benzoin. It is a simple matter physically and psychologically to put them on for a few weeks if the feet show a tendency to slide back into deformity after immobilization has been discontinued. The child's ankles are free to wiggle and the parents are not faced with the terrifying prospect of the child's going back to casts. If it is decided to change the degree of correction, the extension of the splint along the outer side of the foot can be bent out more or straightened, and when the foot is held to the splint by the strap on the fore part of the foot the desired position can be attained. We have been using this splint for five years and find it satisfactory.

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Proceedings

AMERICAN MEDICAL ASSOCIATION

SECTION ON ORTHOPAEDIC SURGERY

As Prepared by H. Herman Young, M.D., *Secretary*, Section on Orthopaedic Surgery

The 1958 Annual Meeting of the Section on Orthopaedic Surgery of the American Medical Association was held in San Francisco, California, June 24 through June 27, 1958, under the Chairmanship of Frederick R. Thompson, M.D., New York, N. Y. A brief review of the sessions and a résumé of each paper presented follows:

The meeting on June 24 opened at 2:00 p.m. The following papers were presented and discussed:

Postoperative Osteomyelitis of the Hip Joint. Dr. Lewis N. Cozen [1], Dr. Edward T. Kelley, Jr., and Dr. Jean E. Michels presented the cases of sixteen male patients who suffered from septic arthritis and osteomyelitis of the hip following surgical procedures. In eleven, arthritis and osteomyelitis were secondary to open reduction of fractures and in five, they followed arthroplasty. Although this complication is relatively rare, it is a tragic disease with a dismal prognosis. The organism most frequently encountered was a resistant staphylococcus. In spite of antibiotic therapy and, occasionally, radical surgical procedures, seven of the sixteen patients still had draining sinuses after follow-up periods of from one to thirty-seven years, although eleven of the patients were ambulatory. No solution was offered to the problem of this postoperative complication, but stress was placed on prevention of the infection as the best solution.

In the conclusion of the article, it was stated that acute osteomyelitis can and does follow surgical procedures on the hip and frequently will be followed by chronic osteomyelitis that will make subsequent operations on the hip necessary. Happily this is an infrequent disaster, but the unfortunate patient with this infection has a painful, deformed joint with constant drainage that sorely taxes both the patient and his physician. Scrupulous aseptic technique was stressed during any surgical procedure near the hip joint to avoid this disaster, but if it does occur, vigorous treatment should be instituted to prevent deep-seated chronic infection. Although a few of the patients seemed to improve after arthrodesis of the hip, not this, but prevention was recommended as a solution of the problem.

Degenerative Arthritis of the Lumbosacral Joint. The End Space Lesion. Dr. John C. Wilson, Jr. [2] drew attention to the fact that degenerative disease of the lumbosacral joint is a specific entity that is not generally well understood by physicians. The symptoms are usually low-back pain, with or without sciatica, stiffness in the morning, and chronic low-back pain with activity. Examination discloses restricted motion of the back, usually some lumbosacral tenderness, and occasionally signs of irritation of nerve roots. The history and physical findings would make one suspect the entity, but roentgenograms of the lumbar portion of the spinal column are needed for verification. Degenerative changes occur in the lumbosacral joints in the young as well as the elderly individual, and there may be a familial predisposition to the condition. Roentgenograms usually show narrowing of the lumbosacral joint with marginal lipping and sclerosis, loss of the joint space, or a collapse of the posterior portion of the lumbosacral joint. This lesion may be slowly progressive. If symptoms referable to the disc are present, and treatment with support, physical therapy, and the use of a bedboard does not suffice, a small percentage of affected patients, roughly 18 per cent, may require fusion of the joint coupled with removal of a protruded intervertbral disc if one is found.

In discussion, Dr. Frederick L. Liebolt [3] pointed out that his experience with this condition had been the same as that of Dr. Wilson. Dr. Liebolt stated that the ratio of patients with this problem is usually two women to one man and that in the majority symptoms develop during the third or fourth decade of life with the attacks preceded by physical exertion, emotional stress, and generalized fatigue. Although, in his experience, many of the patients presented themselves with the complaint of sciatic pain, only a few of them actually showed evidence of protrusion of an intervertebral disc. He stated that satisfactory results had been gained by fusion alone without exploration of the spinal canal but that some patients might well have a protrusion of an intervertebral disc which would require removal of the disc prior to fusion.

Although both the author and the discussor agreed that the intervertebral disc immediately above the fused area may wear down in time, this is not a reflection on the original operation

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for the original symptoms. It was reported by both the author and the discussor that, if the diagnosis is correct and the fusion is performed properly and successfully, the relief of symptoms is most gratifying.

Hanging Cast Treatment of Acromioclavicular Separations and Selected Clavicular Fractures. Dr. Samuel G. Stubbins[4] and Dr. Wilbert H. McGaw pointed out that in the past approximately sixty closed and open methods have been described for treating separation of the acromioclavicular joint. The multiplicity of methods proclaims that the search for better methods still goes on. They reported the treatment of eighteen clavicular fractures and five acromioclavicular separations, all with good results. In their method a cast was applied around the chest with two straps placed over a pad on the shoulder; the cast elevated the scapula and also depressed the clavicle. This hanging cast allows the patient to be ambulatory, and he has the free use of his arm. This hanging cast utilizes the principle of gravity when the patient is upright and the principle of gentle pressure and counterpressure when he is lying in bed. The cast remains on through a period of five to six weeks. Buckles are incorporated into the straps for the purpose of increasing the downward pressure on the clavicle. The results of this method in the cases presented were most gratifying, but it was felt that a more thorough examination of the method is necessary in order to evaluate this type of treatment.

Late Results of the Treatment of Legg-Perthes Disease. Dr. Warren G. Stamp[5], Dr. Gregorio M. Canales, and Dr. Richard T. Odell reviewed the late result of the treatment of Legg-Perthes disease as observed in St. Louis, Missouri. Since 1926, a total of 224 patients were treated at the Shriners' Hospital for Crippled Children in St. Louis by several different methods. The methods employed ran from no treatment to prolonged rest in bed and traction. The epiphyseal quotient and the presence of symptoms were used in evaluation of the end results. The authors were able to follow approximately 146 of their patients. They found that those treated with traction and rest in bed obtained the most satisfactory results, with thirty-one patients having good results, ten fair, and three poor results. Of the patients treated with crutches and a sling, fourteen had good, seven had fair, and ten, poor results. Of those treated with crutches and a lift on their shoe five had good results, eleven had fair, and eleven, poor results, whereas only six of those given no treatment at all but allowed to proceed with weight-bearing obtained good results, eight obtained fair results and thirty, poor results.

It was pointed out that patients treated by the ambulatory method are not controlled as adequately as those treated by rest in bed. The child with Legg-Perthes disease occasionally may bear weight on the limb in spite of precautions against it, and thus the most adequate protection is rest in bed and traction.

The conclusions of the authors indicate that protection against weight-bearing in Legg-Perthes disease until the process has had a chance to enter into and complete the degenerative phase is the most valuable treatment.

The Use of Sympathetic Blocks in Orthopaedic Surgery. Dr. John J. Brennan[6] reviewed the use of sympathetic blocks and advocated their employment both early and prophylactically in the treatment of injured patients. This treatment naturally was directed against the development of the reflex sympathetic dystrophy, but the author did not recommend waiting for full-blown symptoms to develop before employing it. He stated that if any one sign appeared, the block should be performed and physical therapy should be carried on while the effect of the block was still present. One hundred consecutive orthopaedic patients were so treated. These patients had various lesions, from bursitis only through fractures, dislocations, tendon injuries, and an impending Volkmann's ischaemic contracture. With the use of sympathetic block, physical therapy progressed more easily, gave better results, and the swelling of the extremity was lessened. Intermittent blocks were frequently necessary, and at least 53 per cent of the patients benefited by their use. When symptoms of sympathetic dystrophy developed, the patient recovered earlier with the use of a sympathetic block than without it. One hundred consecutive orthopaedic cases in which sympathetic blocks were employed were reviewed, and it was concluded that valuable time was saved in rehabilitation of the patient by the early use of the sympathetic block.

The Second Scientific Session of the Section on Orthopaedic Surgery of the American Medical Association was opened Wednesday, June 25, at 2:00 p.m. at the Mark Hopkins Hotel by Dr. Frederick R. Thompson, New York, N. Y. The following papers were presented:

The Grice Extra-articular Subastragalar Fusion in the Cerebral Palsy Patient. Dr. Lenox D. Baker[7] and Dr. Richard A. Dodelin stated that during the past five and one-half years the Grice operation, which was originally described for other conditions, was being applied to the patient with cerebral palsy. They pointed out that surgery could help the patient with

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7. Duke Hospital, Durham, North Carolina

cerebral palsy and is not necessarily the last resort. Although the Grice operation was described originally for the patient with poliomyelitis, the indication for this operation in the patient with cerebral palsy is the same as for all patients with pronated feet, that is, inversion of the heel, prominence of the astragalus, and abduction of the fore part of the foot. The authors reported on use of the operation on twenty-nine feet of seventeen patients whose ages ranged from three to thirteen years. The operation caused no interference with growth. Complications did occur, but were not frequent. The most common complication was too much varus position of the foot. This deformity, however, was corrected by tenotomy. Only one patient is not walking at the time of the report. The authors expressed the view that use of the Grice procedure coupled with tenotomy, neurectomy, and other procedures has made walking possible for many patients.

The Orthopaedic Management of Neuropathic Joints. Dr. Alan DeF. Smith [8], Dr. Balu Sankaran, Dr. Robert L. Samilson, and Dr. Frank A. Bersani made a study of eighty-seven neuropathic joints in fifty-five patients. The diagnosis was tabes dorsalis for forty-two patients, syringomyelia for four, diabetic neuropathy for four, and alcoholic neuropathy for one. For the most part, however, the condition could be classified as Charcot knees or hips. Not all of the affected joints were painless. Swelling and instability of the joint were evident, and the roentgenographic findings were those of destruction of the joint with additional proliferation of bone.

The most satisfactory method of treatment was fusion, whether a hip or a knee was involved. The authors advised early operation and stated that all of the pseudarthroses occurred when operations were delayed five years or longer after onset of the condition. Arthrodesis was performed on twenty-three joints; solid fusion was obtained in fourteen. The authors stated that the sooner arthrodesis was performed, the better the chance of success. Of twenty-three joints surgically treated, thirteen were knees. The authors expressed the view that the knee lent itself more satisfactorily to arthrodesis.

Neurotrophic Ulcers of the Foot. A Review of Forty-seven Cases. Dr. Patrick J. Kelly [9] and Dr. Mark B. Coventry reported forty-seven cases of neurotrophic ulcers of the feet. Diabetes was the major cause with myelodysplasia as a less frequent cause. The best means of control was control of the underlying condition together with use of properly fitted shoes, padding, and other such measures. The operations on these patients varied from simple débridement of the ulcer alone to skin graft, excision and closure or excision and secondary healing to amputation.

The neurotrophic ulcer has not received adequate attention. The hallmark of the diagnosis is a persistent ulcer on the foot of the patient having diabetes, myelodysplasia, syringomyelia, or other less common causes of neurotrophism. Whenever possible, conservative treatment was emphasized but surgical treatment was advocated when necessary.

The Chairman's Address. Dr. Frederick R. Thompson [10] gave an excellent résumé of surgery and reconstruction of the hip. He pointed out the many advances that have been made in treatment of osteo-arthritis of the hip and the fact that the ultimate in surgical treatment has not as yet been reached, but that surgical advances are being made. The subject was reviewed completely and suggestions were made concerning the future course of surgery of the hip joint.

Congenital Spinal Curvature Treated by Fusion. Dr. Charles A. Porretta [11], Dr. William H. Bickel, and Dr. John H. Moe presented an analysis of the data on forty patients, twenty-eight girls and twelve boys between the ages of one and nineteen years, who had congenital anomalies of the spinal column associated with scoliosis, kyphoscoliosis, or kyphosis treated by partial correction of the curvature and fusion. Operations were carried out without the development of lordosis as was prognosticated. The average correction of the scoliosis was 30 degrees. There was an average loss of 12 degrees in correction, although there was no loss in nine patients. Pseudarthrosis developed in 35 per cent of the patients, but this was controlled by secondary operations. It was pointed out that all vertebrae in the primary curve should be fused. Data on nine patients who had kyphoscoliosis or kyphosis but were not treated by fusion were also reviewed. Two of these became paraplegic, and three had curvatures of more than 120 degrees as a final result. No paraplegia and no curvature of more than 90 degrees were present as a final result in the operative series.

The Medical Legal Aspects of Whiplash Injury. Dr. Charles J. Frankel [12] pointed out that so-called whiplash injuries to the spine are rapidly taking their place among the leading

8. 180 Fort Washington Avenue, New York 32, N. Y.
9. Mayo Foundation, Rochester, Minnesota
10. 16 East 90th Street, New York 28, N. Y.
11. Mayo Foundation, Rochester, Minnesota
12. University of Virginia Hospital, Charlottesville, Virginia

causes for litigation and that attorneys have seized on the term "whiplash injury" and have misused it with gusto. He would substitute the term "necklash injuries", and he analyzed the injuries to the cervical vertebrae as to the mechanics involved. Dr. Frankel made a plea for more accurate diagnosis, more nearly correct terminology, and a non-partisan attitude on the part of physicians who examine many of these patients. He recommended that any medical or pseudo-scientific report which flatly infers that 80 per cent of persons who receive injuries to the neck in automobile accidents are malingerers, should be re-examined closely.

There was much discussion of this paper, all of which pointed up the fact that there is considerable need of clarification of the injury to the neck in an automobile accident.

The Third Session of the Section on Orthopaedic Surgery of the American Medical Association was opened on Thursday, June 26, at 2:00 p.m. at the Mark Hopkins Hotel. The first order of business was the election of officers. The following slate was presented by the Nominating Committee and unanimously elected:

Chairman of Section: Lenox D. Baker, M.D., Durham, North Carolina;
Vice-Chairman: H. Herman Young, M.D., Rochester, Minnesota;
Secretary: Robert J. Joplin, M.D., Brookline, Massachusetts;
Assistant Secretary: John C. Wilson, Jr., M.D., Los Angeles, California;
Representative to Scientific Exhibit: James I. Kendrick, M.D., Cleveland, Ohio;
Delegate: H. Relton McCarroll, M.D., St. Louis, Missouri;
Alternate Delegate: Harry Walker, M.D., Oakland, California.

Following the business session the following papers were presented:

Upper-Arm Block Anaesthesia in Children, with Special Reference to Its Use in Fractures. Dr. Mack L. Clayton[13] and Dr. Donald A. Turner said that upper-arm block by the axillary route as described by Adriani and Accardo is an excellent, safe method of regional anaesthesia. From injection of ten cubic centimeters of a 2 per cent solution of lidocaine hydrochloride (xylocaine) into the axillary plexus directly in the axilla, good regional anaesthesia was obtained. By this method the nerve supply of the arm is blocked without the possibility of thoracic complications, such as those from supraclavicular blocks which are at times serious. The authors pointed out that this type of block had been successfully used, particularly in children, and is useful in the treatment of recent fractures, as one should assume that there is food in the child's stomach, and the risk of aspiration of gastric contents is great when general anaesthesia is employed. The reports on its use for reducing supracondylar, forearm, and wrist fractures were good, and the resulting sympathetic block was also of value in certain cases. The technique is simple. The children have not objected to the needle and have cooperated well. In forty consecutive cases there was only one failure.

A Physiologic Treatment for Fractures of the Metacarpals and Phalanges. Dr. Preston J. Burnham[14] stated that fractures of the metacarpals and the proximal and middle phalanges have offered the greatest problems in reduction and immobilization due to the strong distorting tensions on the bones by the long and intrinsic muscle-tendon systems. A method of controlling both fragments is needed, and the part should be put up in the position of rest with immobilization of the entire ray. The author presented a technique by which the surgeon can anaesthetize, reduce, and immobilize these fractures, without assistance, on a new type of splint. The splint is a curved finger splint which immobilizes the wrist and metacarpals first. It is covered with plaster and then the fracture of the finger is reduced and the bones held in place on the incorporated splint. The results presented were good, but some questions were raised concerning the control of rotation of the fragments by the method presented.

Fractures of the Tibial Plateau. Dr. Vernon C. Turner[15] discussed the complicated and disabling injury—fracture of the tibial plateau. The author stated that aspiration of the joint to relieve pain, followed by manipulation and skeletal traction in a Thomas splint with a Pearson attachment is necessary. Early active and active-assistive motion are important in the care of the patient. The author then employs a brace with a double bar and pressure pads, and encourages use of exercises together with early walking with brace and crutches, continued use of exercises, and a long period of protected weight-bearing.

Although conservative treatment is best for the non-displaced fracture and surgical intervention is best for the seriously displaced fracture, the author stated that the middle of the road problem is the most difficult to solve. In the discussion, Dr. J. Vernon Luck[16] expressed the opinion that if displacement of more than one centimeter is present, open reduction is necessary.

13. 830 East 18th Avenue, Denver 18, Colorado
14. 508 East South Temple Street, Salt Lake City 2, Utah
15. 636 Church Street, Evanston, Illinois
16. 1930 Wilshire Boulevard, Los Angeles 57, California

A Treatment for Comminuted Fractures of the Os Calcis. Dr. Chester R. Zeiss[17] presented a method of treatment of comminuted depressed fractures of the os calcis, an attempt being made to restore Boehler's angle. In this method a Steinmann pin is placed into the os calcis, and with this as a lever the posterior portion of the os calcis is depressed downward and Boehler's angle restored. The Boehler clamp is applied to correct the transverse spread of the fractured os calcis, and the entire extremity is placed in a cast. After this the nail is removed.

In the author's experience, the results of treatment have been gratifying in that all patients have been able to resume previous occupations with minimal discomfort. The discussor considered his series of patients too small to be of statistical value but stated that the method may have considerable merit.

Internal Fixation of the Fibula in Fractures of Both Bones of the Leg. Dr. E. Burke Evans[18] said that fixation of the fibula, when it is involved, may be useful in treating the following types of tibial fractures: (1) fractures of the extreme proximal or distal third, (2) comminuted fractures of the shaft, (3) compound fractures with marked loss of soft tissue, (4) non-union of fractures in proximal or distal extremes, and (5) suppurating non-union of fractures at any level. The author reviewed the technique of using the slotted plate or intramedullary rod to fix the fibula and thus help stabilize the tibial fractures. This method of providing stabilization was used by him mainly for comminuted or unstable fractures of the lower third of the tibial shaft. Occasionally it was used to help stabilize an ununited fracture. With stabilization of the fibula, length and often alignment were restored to the tibia; then the fragments could be manipulated if necessary or even further stabilized by means of transfixation, the fibula serving as a splint. The hazards and possible complications of the proposed method were reviewed.

In summary it was pointed out that the fibula was a natural splint for the tibia and might be employed to serve as such in certain fractures of both bones of the leg, which, because of the involvement or degree of comminution or compounding, are difficult to handle. Open reduction with internal fixation of the fibula alone has been an effective method of treatment by the author in four distinct problems of fracture of the leg: (1) the supramalleolar fracture, (2) comminuted fracture of the shaft, (3) transcondylar fracture, and (4) fracture with non-union or malunion. It was felt that in this method the use of the fibula as a splint converted a fracture of both bones into one of the tibia alone, restored the length and alignment of the tibia, and gave a certain degree of stability. This method facilitated manipulation and eliminated undue handling of tibial fragments as well as allowing approach through uninjured skin and soft tissue in compound fractures. It was also thought that this method added stability for grafting when non-union was present, enhanced the efficiency of plaster, and reduced the morbidity of the fracture. The author reported such gratifying results in the treatment of fifteen fractures that he now considers this the method of choice.

Complications of Traction Treatment of Supracondylar Fractures of the Humerus in Children. Dr. O. Sherwin Staples[19] stated that for the widely displaced supracondylar fracture of the humerus in children, careful evaluation and thoughtful selection of treatment and constant vigilance remain essential. Opinion varies as to what constitutes the best form of routine management, and traction methods are being widely used as a so-called safer method of management of these rather severe injuries. Treatment by traction, however, is not without its complications and possibility of errors of judgment and technique.

This paper presented the problems that have arisen in one clinic during ten years of treatment by traction of supracondylar fractures in children. In this period, eighty-six children who had supracondylar fractures were observed. For the thirty-seven fractures with little or no displacement, only fixation with a cast was required. Of the others, seventeen were treated by manipulation and splinting, and thirty-one by traction with or without open reduction. In the group of patients whose fractures were treated by traction, approximately half were seen for the first time after manipulative treatment had been tried unsuccessfully elsewhere and often after one or two days' delay. One of these patients arrived late with serious vascular injury and Volkmann's ischaemic contracture developed. With this one exception, the patients treated by traction recovered normal or almost normal function without significant deformity, although results at the end of the period of growth were not available. For seven of the thirty-one fractures, traction alone was ineffective or complications developed. In one patient overriding of the fragments occurred; at that time the patient's pain became severe with evidence of decreased circulation in the hand. With reduction of traction, the circulation reverted to normal. Although less than perfect position, by roentgenographic examination, was accepted, union occurred without demonstrable loss of function except the 5-degree loss of flexion of the elbow. A second patient demonstrated the possibility of nerve and vascular im-

17. 1150 West 78th Street, Chicago 20, Illinois
18. University of Texas, Medical Branch, Galveston, Texas
19. 2 Maynard Street, Hanover, New Hampshire

pairment with distraction of fracture fragments. In other patients an artery was so displaced that it was caught between the two fragments and could not be replaced by traction alone. Open reduction was necessary.

The author concluded that no one single method could be applied universally as treatment for the displaced supracondylar fracture of the elbow, but that there must be careful selection of treatment and constant vigilance no matter what type of treatment is selected. In spite of the experience reported, however, the author stated that treatment by traction had an important place in the management of severe supracondylar injuries.

The final day of the meetings of the Section on Orthopaedic Surgery of the American Medical Association was opened Friday, June 27, at 9:00 a.m. at the Mark Hopkins Hotel in a joint meeting with the Section on Physical Medicine. This joint meeting was concerned with a "Symposium on the Diagnosis and Treatment of Pain in the Shoulder and Arm", participated in by Edward H. Morgan, M.D., Seattle, Washington; Paul C. Bucy, M.D., Chicago, Illinois; Jesse T. Nicholson, M.D., and Henry S. Wieder, Jr., M.D., Philadelphia, Pennsylvania; John W. Pender, M.D., Palo Alto, California; and Paul A. Nelson, M.D., Cleveland, Ohio.

Dr. Edward H. Morgan [20] opened the discussion with a presentation of the significance of pain in the shoulder and arm arising from visceral and systemic illnesses. He pointed out that the important origins include cardiac, pericardial, pleural, and pulmonary disorders but also emphasized the fact that pain in the shoulder and arm may originate from any lesions involving the diaphragm such as gallbladder disease and perforating gastric ulcer. Even a ruptured tubal pregnancy should be suspected. In other words, emphasis must be placed on the fact that when pain in the shoulder and arm cannot be explained by a local cause, one must look elsewhere, even to the thoracic and abdominal viscera, for the source of the pain.

Dr. Paul C. Bucy [21] then explained the various neurological lesions which might be responsible for pain in the upper extremity. These included lesions of the spinal column as well as those within the spinal canal, such as tumors, herniated intervertebral discs, and arthritic spurs. Lesions of the brachial plexus and lesions of peripheral nerves, likewise, may lead to the development of such symptoms. Probably the most common cause of such referred pain is protruded intervertebral disc in the cervical region.

Dr. Jesse T. Nicholson [22] and Dr. Henry S. Wieder, Jr. [23] then reviewed the causes of pain in the shoulder and arm. Bursitis, tendinitis, adhesive capsulitis, subluxations, fractures, and tumors, among other conditions, may involve the shoulder joint and may be the source for the complaint.

Dr. John W. Pender [24] considered the shoulder-arm syndrome and stated that sympathetic-nerve block would be a valuable adjunct to other forms of treatment, but that alone it rarely is adequate. He suggested that the anaesthetist might help in treating patients with a shoulder-arm syndrome. Repeated blocks of the stellate ganglion and sympathetic trunk can be effected with aqueous anaesthetic solutions, with only a low incidence of complications. He preferred this procedure, but for the unusual circumstance when a prolonged block is desired an alcohol injection might be used. When it is used, however, roentgenograms are necessary to aid in the accurate placement of the needle before the injection.

Dr. Paul A. Nelson [25] then reviewed the type of physical therapy that might be effective in the management of the patient who complains of pain in the shoulder and arm, particularly the patient whose pain originates from a localized condition in the shoulder or arm itself. The application of various forms of heat and massage is helpful in relieving pain and muscle spasm and in increasing the flow of blood. Exercises, when carefully prescribed, tend to correct the underlying pathological condition and thus have a more permanent effect than use of heat and massage alone. He reviewed the use of cervical traction with the Sayre head sling for relief of pain of the neck and shoulder, especially for patients having irritation of a cervical-nerve root from an osteophytic overgrowth, or protrusion of an intervertebral disc, or headache from severe tension. Finally, he mentioned that the sympathetic attitude and reassuring manner of the physical therapist have, to a certain extent, a positive psychotherapeutic effect.

20. 1118-9th Avenue, Seattle 1, Washington
21. 250 East Superior Street, Chicago 11, Illinois
22. 1740 Bainbridge Street, Philadelphia 46, Pennsylvania
23. 330 South 9th Street, Philadelphia 7, Pennsylvania
24. 300 Homer Avenue, Palo Alto, California
25. 2020 East 93rd Street, Cleveland 6, Ohio

FORUM ON FUNDAMENTAL PROBLEMS IN ORTHOPAEDIC SURGERY

Meeting of the American College of Surgeons

October 6, 1958

As Prepared by Crawford J. Campbell, M.D., Albany, New York

Freeze-Dried Bone Homografts. Dr. M. K. Myint[1], Dr. W. T. Fitts, and Dr. B. Roberts found, in experiments done on dogs, that the results using freeze-dried homogenous-bone grafts did not compare favorably with their previously reported results using fresh autogenous-bone grafts and fresh homogenous-bone grafts. Freeze-dried circumferential cortical homogenous-bone grafts from 1.5 to two centimeters in length, were inserted into defects produced in the mid-shaft of femora as follows:

Lot 1. In ten dogs they used bone which was freeze-dried for two weeks at a pressure of 150 micra of mercury. Three dogs died before firm bone union was present although there was some new-bone formation. One dog had complete absorption of the graft; two dogs had severe infections and were discarded. There was satisfactory healing in four dogs.

Lots 2, 3, and 4. In these thirty-four dogs they used bone which was freeze-dried at separate times for seven days each at a pressure of less than fifty micra of mercury; the results were worse. The grafts were successful in only nine dogs.

Anterior Fusion of the Lumbar Spine Using an Internal Fixation Device. Dr. A. W. Humphries[2], Dr. W. A. Hawk, and Dr. A. L. Berndt used a new technique in performing spine fusion on twenty-five dogs. Through the anterior transperitoneal approach, the disc and its remnants were excised, the opposing cortical plates of the adjacent vertebrae were removed and the space filled with fragmented homogenous cancellous-bone chips. An intervertebral clamp was fitted and then fixed to the vertebrae with four screws. Roentgenograms and microscopic sections made at intervals up to six months postoperatively showed firm bone fusion. In a control series, similar to the above with the exception that the intervertebral clamp was not used, pseudarthrosis resulted in every instance.

The Experimental Use of Novobiocin (Cathomycin) and Antibiotics in the Treatment of Experimentally Produced Purulent Arthritis. Dr. Charles J. Frankel[3], Dr. David K. Webster, and Dr. A. Brant Lipscomb determined the effectiveness of the intra-articular treatment with novobiocin in rabbits whose knee joints were infected with a penicillin-resistant coagulase-positive hemolytic *Staphylococcus aureus*. The animals were sacrificed at fourteen days. The authors found only a minimal oedema and inflammatory response following the intrathecal injection of novobiocin. No antibiotics were given following the injections of the organisms; a purulent septic arthritis developed rapidly and cultures were positive. In those animals treated with novobiocin after the intrathecal injection of the penicillin-resistant *Staphylococcus aureus*, there was a chronic inflammatory reaction which was more pronounced than in those given an injection of novobiocin alone. There was no necrosis or acute inflammatory reaction as noted in the preceding group and the cultures were negative.

The Effect of Environmental Influence on Acetabular Development. Dr. C. R. Coleman[4], Dr. R. Slager, and Dr. W. S. Smith found, in experimental work on puppies, that the acetabular shape conforms to that of titanium spheres despite the constancy in size of the spheres during acetabular growth. When titanium cubes were inserted, there was a flattening of the roof of the acetabulum. Following epiphysiolysis the acetabulum was more normal in appearance although smaller in size. Although resection of the cartilaginous limbus caused an increased acetabular obliquity, the hips did not dislocate except in the few in which the ligamentum teres was transected.

Bone and Joint Changes Following Burns. Dr. E. Burke Evans[5] and Dr. James R. Smith found bone and joint changes in twenty of 900 burned patients. Serum calcium, phosphorus, alkaline phosphatase, urinary calcium excreta, and blood culture studies revealed no basic difference between those individuals with bone and joint changes and those without any change. Histological and roentgenographic examination showed the following types of bone and joint changes:

1. Periosteal new-bone formation which was a reaction to an inflammatory process in the bone or joint;
2. Capsular calcification which may or may not underly a burned area;
3. Osteophytic growths—usually in a burned area;

1. University of Pennsylvania School of Medicine, Philadelphia, Pennsylvania.
2. 2020 East 93rd Street, Cleveland 6, Ohio.
3. University of Virginia Hospital, Staunton, Virginia.
4. Ohio State University College of Medicine, Columbus, Ohio.
5. University of Texas, Medical Branch, Galveston, Texas.

4. Heterotopic para-articular ossification which has no dependence on the proximity of the burn and may possibly be due to trauma;

5. Joint destruction and ankylosis may be distant to, or in the proximity of, a burn—the alteration resembles septic arthritis in its behavior.

The authors stated that the basic cause of the heterotopic ossification and calcification following burns is still unsolved.

Effect of Certain Sex Hormones upon the Reproductive Process in Fractures following Motor Denervation in Rats. Dr. William Smith [6], Dr. John L. Wolf, Dr. Carl R. Coleman, and Dr. Richard Slager previously showed that in rats there was delayed union of fracture in a limb rendered osteoporotic by sciatic denervation. In this experiment, the ratio of the P^{32} uptake of the sound limb to the denervated limb was measured at twenty-five, thirty-five, and fifty-five days after fracture and administration of long acting estrogen and testosterone. A significant decrease of this ratio in the group of estrogen-treated rats fifty-five days after fracture suggested a more mature process in this particular group.

A Study of the Growth and Nutrition of Surgically Created Osteochondral Loose Bodies in Adult and Young Rabbits. Dr. Robert W. Bailey [7] and Dr. Robert E. Selle produced osteocartilaginous loose bodies in the knee joints of twenty-seven young and adult rabbits. The animals were sacrificed at two, four, and six months after surgery. Forty-eight hours prior to sacrifice each animal was given an intravenous injection of 300 microcuries of S^{35}, labeled $H_2S^{35}O_4$. Examination of the loose bodies revealed a significant gain in weight. Measurements of S^{35} by direct gas flow counting technique of an HNO_3 isolate showed three times as much uptake of S^{35} in the loose bodies in the knees of the adult rabbits as compared with the young. Microscopic sections showed the greater part of the loose body to consist of bone with a small margin of hyaline cartilage along the periphery. Autoradiography was not successful.

Fat Embolism: Changes in the Serum Lipase Levels of Patients after Fresh Fractures or Orthopaedic Operations. Dr. Leonard F. Peltier [8] and Dr. Sing-Pin Lai found that the level of serum lipase as determined by the twenty-four hour olive oil emulsion method rises during the second and third days after injury and remains elevated for five to seven days in 50 per cent of patients sustaining fractures of sufficient magnitude to require hospitalization and in 20 per cent of patients undergoing elective surgery. In comparing this clinical study with previous experimental work, an elevated serum lipase activity above one milliliter was considered significant.

Therapy of Traumatic Fat Embolism with Intravenous Fluids and Heparin. Dr. C. A. Cobb, Jr.[9], Dr. V. S. LeQuire, Dr. M. E. Gray, and Dr. J. W. Hillman tagged fat emboli with I^{131}. When emboli were introduced into peripheral veins of dogs they were arrested in the lungs. After about four days the emboli were mobilized and metabolism indicated by the appearance of iodide activity in the thyroid. Small emboli (one or two cubic centimeters) introduced in peripheral arteries or the carotid artery are not held in the peripheral vessels but rather in the lungs. Increasing size (four cubic centimeters) leads to increased local arrest.

Examination of the bile and urine following embolization showed substantial amounts of the tagged fat. In animals with bile fistulae the subsequent concentration of iodide in the thyroid was greatly reduced, thereby suggesting that metabolism of the fatty acids may follow excretion by the liver and reabsorption.

Several emulsifying agents were tested and noted to have no effect on the embolization. Heparin led to a more rapid removal of the embolic fat from the lungs and an earlier appearance of iodide.

The authors used heparin and heavy parenteral-fluid therapy successfully in twelve cases of severe traumatic fat embolism.

Experimental Studies on Stability of Internal Fixation of Femoral-Neck Fractures in Autopsy Bone. Dr. J. Paul Harvey [10], Dr. Carl Hirsch, and Dr. Philip D. Wilson used a hydraulic compression machine to test the depletion of intact specimens of the proximal one-third of the femur. After transection of the femoral neck on a line 90 degrees to its longitudinal axis, it was possible to obtain a means of testing internal-fixation devices used in fractures of the hip without taking into account the final breaking point of bone or the individual variation in specimens.

Although the age of the patient made no difference, it was noted that the best deflection ratios occurred in those in whom the fixation device rested on the calcar.

6. Ohio State University College of Medicine, Columbus, Ohio.
7. University of California Medical Center, Los Angeles, California.
8. University of Kansas Medical Center, Kansas City 12, Kansas.
9. Vanderbilt University School of Medicine, Nashville, Tennessee.
10. Hospital for Special Surgery, New York, N. Y.

Polyurethane Polymer (Ostamer): Its Use in Fractured and Diseased Bone. Dr. Michael P. Mandarino[11] and Dr. Joseph E. Salvatore found that rigid polyurethane foam met the requirements of strength, immobilization, non-toxicity, adhesion and cohesion, torsional stabilization, and ease of handling needed for bone surgery.

The prepolymer was prepared by reacting a trihydroxy resin with an excess of di-isocyanate. At surgery this prepolymer was mixed with water and a catalyst. (No excess heat was produced by this reaction.) This method is an attempt to find a chemical compound which can be poured into a fracture site and produce bonding of the fractured ends of bone.

The authors found minimal foreign-body reaction and no evidence of carcinogenesis in seventy rodents in which the polyurethane plastic was implanted subcutaneously. Defects which measured one to 1.5 centimeters were produced in the radii and femora of dogs and then filled with the plastic. No external fixation was employed. Bridging of the defect with bone occurred in 80 per cent of the animals tested.

The authors further stated that over a period of time the polyurethane foam diminishes in volume and softens.

11. Hahnemann Medical College and Hospital, Philadelphia, Pennsylvania.

THE VIRGINIA STATE ORTHOPAEDIC SOCIETY

The annual Spring Scientific Meeting of the Virginia State Orthopaedic Society was held in Charlottesville, Virginia, on March 28 and 29, 1958. Dr. J. Hamilton Allan presided and Dr. Otto E. Aufranc, guest lecturer, spoke on Vitallium Cup Arthroplasty.

Vertebra Plana. Dr. David Strider[1] reported that this entity was first described by Calvé at The British Orthopaedic Association Meeting in Bologna, Italy, in 1924. Until recently the most accepted theory of etiology was that of primary aseptic necrosis of the vertebral body, possibly secondary to trauma or infectious disease. Congenital malformations, endocrine disorders, disturbed ossification processes, syphilis, tuberculosis, eosinophilic granuloma, and Hand-Schüller-Christian disease were cited as possible predisposing causes of vertebra plana. Dr. Strider presented two cases of vertebra plana occurring in twins, each of whom had lesions which were due to eosinophilic granuloma. The author concluded that vertebra plana is not due to any one process but may be a result of any one of several osteolytic lesions.

Management of Knee Injuries in Athletes. Dr. Albert Brant Lipscomb[2] based his report on a study of sixty-seven knee injuries occurring in varsity football games during a five-year period at Vanderbilt University. He evaluated the program of management, emphasizing a conservative approach and intensive quadriceps exercises. He felt that this was indicated because of the increasing tendency for performing immediate arthrotomy in these injuries. The author stressed the conservative approach including meticulous examination, accurate diagnosis, and a strict routine of treatment both for the patients who required operation and those who did not. All but three players were able to participate fully in football after this program. Immediate arthrotomy for repair of torn collateral and cruciate ligaments was not done. From this study Dr. Lipscomb felt that the quadriceps mechanism, when developed to a maximum, can more than adequately compensate for moderate degrees of instability in both the collateral and cruciate ligaments.

Chemopallidectomy in Cerebral Palsy. Dr. David Fairman gave a thorough discussion of this newly developed surgical procedure. It was shown that in carefully chosen cases of cerebral palsy, in which the patient had sufficient intelligence combined with athetosis or rigidity, this procedure at times provided dramatic relief from these uncontrollable motions.

The surgical procedure entails placing a cautery in the area of the basal ganglia by a localizing apparatus, modified by the author, which with x-ray permits the procedure to be done accurately.

Osteopetrosis in Twins. Dr. Charles B. Bray, Jr.[3], and Dr. Tom Hamilton presented cases of osteopetrosis occurring in ten-year-old twins and their fifty-year-old father. These cases have been followed by serial x-rays over a period of years and have shown the classic stigmata of the disease.

A review of the literature failed to reveal any case reports of osteopetrosis occurring in twins. All cases showed elevated reticulocyte counts and decreased serum phosphorus levels.

1. 801 East High Street, Charlottesville, Virginia.
2. 1706 Hayes Street, Nashville, Tennessee.
3. 1240 3rd Street, S.W., Roanoke, Virginia.

Vitallium Cup Arthroplasty. Dr. Otto E. Aufranc[4] gave an excellent review of the development of the cup arthroplasty. In 1938, he and Dr. Carroll Larson assisted Dr. Marius Smith-Petersen during the first Vitallium cup arthroplasty.

Arthroplasty first occurred to Dr. Smith-Petersen in 1923 after removing a piece of glass from a patient's back. There was fluid around the glass and the laboratory reported the lining of the cyst as synovial tissue. Being a keen observer, Dr. Smith-Petersen wondered why such material could not be used or adapted to the hip joint and proceeded to develop first glass, then plastic, and later bakelite cups. All of these proved inadequate and Dr. Smith-Petersen was about to give up the idea when his dentist mentioned the possibility of using Vitallium. It took a year to develop the Vitallium mold and it was first used in 1938. Plans for the hemispheric mold were drawn in 1939 but were not put into use until 1953 since the original models had served so well.

Dr. Aufranc described the operation as a sound surgical procedure which has withstood the test of time. The first patient upon whom the operation was performed in 1938 had it repeated on the other hip and is still getting around well.

The author told how helpful suggestions were made for carrying out this procedure. He incised the fascia starting distally and then dissected toward the pelvis. This helps to separate the tensor fasciae latae and the sartorius which blend together at the pelvis. The glutaeus minimus is divided at the insertion to the greater trochanter rather than stripped from the pelvis. This reduces bleeding and is easier to resuture. Before dislocating the hip he removes a small rim of the anterior acetabulum (approximately one-fourth of an inch). He also feels it important to remove the insertion of the iliopsoas and to insert it into the anterior capsule. This helps hold the hip in a neutral positon and has helped to prevent dislocations which occurred in some of the earlier cases. A loose fit was advocated with the original cups; however, with the hemispheric mold the fit should be tighter.

Postoperatively, crutches are used as long as there is pain and a cane as long as there is limp. Exercises are most important and should be done for the rest of the patient's life. He also pointed out that the patient should not sit for more than thirty minutes at a time, especially for two years following the procedure, as this would increase the chance of flexion deformity.

Part of the program for March 29 consisted of a tour, led by Dr. Allan, of the recently finished Children's Rehabilitation Center in Charlottesville. The building has the latest facilities for rehabilitating children.

Factors Influencing Healing Time in Fractures of the Tibia. Dr. E. D. V. Nicoll[5] presented a report on 113 patients with fracture of the shaft of the tibia examined during the past seven years at the University of Virginia Hospital. The healing time was determined and the treatment subjected to critical review.

Fracture of the shaft of the tibia should be reduced within a few hours of the injury and the reduction should be maintained uninterruptedly until the fracture has united. Union will occur in about six months in most patients whose cases are uncomplicated. In the survey some united in thirteen weeks; however, some apparently uncomplicated cases required more than a year to unite.

The causes of delayed union are: (1) delayed reduction; (2) repeated manipulation or too early weight-bearing; (3) failure to reduce the fracture, leaving a gap which must be bridged by new bone; (4) severe comminution, leaving fragments denuded of their blood supply; (5) distraction; and (6) infection.

When all cases of delayed or slow union are studied, some will not fall into any of the categories just mentioned and no mechanical cause for delayed union can be found. Perhaps these cases illustrate the participation of the skeletal system in the general adaptation syndrome of Selye.

Bone Tumors. Dr. Robert Kindred[6] based his report on a study of 6,000 cases of bone tumor at the Armed Forces Institute of Pathology. A review of a theory of bone tumors was presented in order to define the following relationships in primary neoplasms of bone: (1) histology; (2) mixed types; (3) change in character when spreading from bone; and (4) character of the matrix in relationship to the biological forces in the area in which the tumor arises.

Whiplash Injuries. Dr. Charles Frankel[7] pointed out that physicians handling these cases should be most thorough in their evaluation of these patients. Observation of these patients should include noting the presence or absence of pharyngeal oedema and evidence of Horner's syndrome, as well as the other more commonly recognized findings associated with this condition.

4. 266 Beacon Street, Boston, Massachusetts.
5. University of Virginia Hospital, Charlottesville, Virginia.
6. Alfred I. DuPont Institute, Wilmington, Delaware.
7. University of Virginia Hospital, Charlottesville, Virginia.

JAPANESE SOCIETY FOR SURGERY OF THE HAND

The Second Annual Meeting of the Japanese Society for Surgery of the Hand was held at the Osaka International Salon, Osaka, Japan, on July 13, 1958. Two hundred members and 300 guests were present. The meeting opened with an inauguration speech by the President, Dr. S. Mizuno, Professor and Director of the Department of Orthopaedic Surgery of the Osaka City University Medical School. Dr. Mizuno and colleagues from Osaka City University presented results of a series of animal experiments dealing with the central blood supply in tendons. The Okayama team, directed by Asst. Prof. Tsuge, reported on oedema in tendons resulting from tendon suture. A group of men from Osaka National University showed a beautiful illustration of electromyographic studies of the function of individual muscles. Prof. Amako and his associates from Kyusyu presented detailed anatomical studies dealing with the function and variations of tendons. The Tokyo Medical College team, directed by Prof. Nozaki, described a new method of prehensile force. A group under the direction of Asst. Prof. Tazima of Niigata University, gave an excellent report on the use of artificial arms. Prof. Kasiwagi, directing the Kobe team, discussed the grading of disabilities in hand deformities. Prof. K. Suzuki, from the Department of Anatomy of the Osaka City University, presented some histological preparations of motor-nerve terminals in striated muscles.

After a short coffee break the second part of the scientific program was opened. This part of the program concerned the surgical aspects of hand surgery. Prof. Onchi and his associates from Nara presented the details of a new type of surgical table for use during hand surgery. He also illustrated the importance of stellate ganglion block in circulatory disorders in the hand. The group of doctors from First National Tokyo Hospital demonstrated their method of plastic surgery for contracture of the digits. The Kyoto team, directed by Prof. Kondo, discussed their experiences with leprosy. The Okayama team showed cases of radial palsy. Colleagues from Kwansai Industrial Accident Hospital reported their experiences with phalangization. Prof. Ueda, directing the group from the Nagova City Medical College, discussed bone-grafting. Prof. T. Akiyama, of the Tokyo Dental College, pointed out the role of various resins in hand surgery. These resins may be very promising, either in repair and reconstruction or in the prosthetic field.

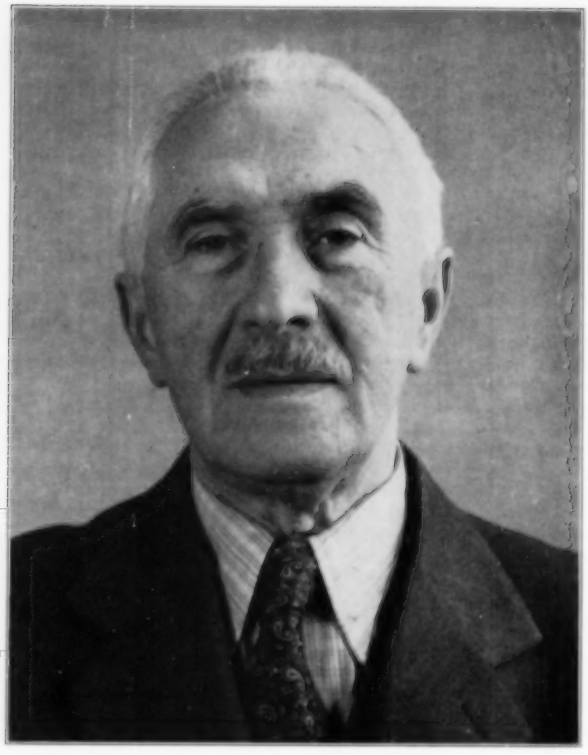
Four instructional course lectures were given in the afternoon. Prof. T. Morotomi, from Hirosaki, showed fundamental surgical techniques in treating cicatricial contracture of the hand. He advocated a method of skin-grafting with numerous pin holes. Assoc. Prof. K. Tuge, from Okayama, illustrated the basic surgical techniques in treating tendon injuries. Asst. Prof. T. Tazima, from Niigata, gave an excellent report of a case of pollicization with a neurovascular pedicle. Prof. S. Mizuno, from Osaka, pointed out the aim of repair and reconstruction of the hand, using a newly constructed splint.

The third part of the scientific program consisted of case reports reported by groups from the Osaka City University, from Hirosaki, directed by Prof. Morotomi; from Tokyo Medical College; from Kagosima, directed by Prof. Miyazaki; from Nippon Medical College, directed by Asst. Prof. Mizutani; from Zikei Medical College, directed by Prof. Katayama; from Tohoku, directed by Prof. Iino, and by Prof. Kazima from Osaka.

A clinical conference took place simultaneously. Under the chairmanship of Prof. Kasiwagi, from Kobe, several experts in hand surgery answered questions presented by the members. Dr. Kosimune, from Osaka, presented reports of several serious cases of flexor-tendon injuries needing many operations. Prof. Onchi and his group from Naia presented a case of total skin defect of the hand without any deeper lesion, and discussed the method of skin-grafting. Dr. Nakano, of Kobe, reported cases of mallet-finger and one case of severe injury caused by electrical shock. Dr. Miyamoto, of Amagasaki, presented a case showing the late development of a circulatory disorder causing flexion-contracture in a hand with extensive cicatricial contracture.

The audio-visual program was held at 4 P.M. Dr. Toriyama, from Tokyo, showed his technique for the repair of ruptured long extensor tendons of the thumb. Dr. Tazima, from Niigata, illustrated the basic principles of hand surgery. Dr. Tuge from Okayama showed a detailed explanatory film on the reconstruction of claw-hand in leprosy, employing Bunnell's principles of reconstruction of the opponens pollicis and lumbricales.

At the beginning of the business session all of the members and guests stood for a moment in silent tribute to express their heart-felt sympathy at the death of Dr. Sterling Bunnell. The next meeting will be held in Tokyo in the autumn of 1959, under the Presidency of Prof. Iwahara of Keio University.



PROF. DR. JAN ZAHRADNICEK

1882-1958

With the passing of Jan Zahradnicek on October 12, 1958, Europe lost one of her most beloved and venerated orthopaedic professors. For nearly thirty years he was Chief of the First Orthopaedic Clinic of Charles University in Prague. He began his career as a general surgeon in Brno, Moravia, and, in 1926, he came to Prague to Prof. Kukula's clinic. He was for many years President of the Czechoslovak Orthopaedic Society.

Prof. Zahradnicek wrote over eighty scientific works among which were four monographs: Anomalies of the Vertebrae, Surgery of the Locomotor System, Hypertrophic Arthritis, and Treatment of Congenital Dislocation of the Hip. The latter is, perhaps, his outstanding work. His interest centered about the hip joint because of the frequent occurrence of congenital dislocation in his country. He led a crusade for the early recognition of the condition and for conservative, non-forceful reduction as a means of obtaining a concentric position of the head in the acetabulum. His surgical procedure of pertrochanteric wedging and shortening of the upper portion of the femoral shaft by resection was revolutionary. By the establishing of normal lines of stress, many late deformities were prevented from developing.

His tall distinguished figure, his kindly face, and gentle manner will be missed by the hundreds of patients he served. He will be mourned by his many devoted contemporaries and students. He leaves a charming wife, who is herself a doctor, and two doctor sons who are following in his footsteps. To them all he leaves a precious heritage of untiring devotion to his specialty.

Jaroslav Slavik

News Notes

The Annual Meeting of **The American Orthopaedic Association** will be held at the Lake Placid Club, Lake Placid, New York, June 15 through 18, 1959.

An **Orthopaedic Seminar for Residents in Orthopaedic Surgery** (being trained in New England, New York, New Jersey, Pennsylvania, Delaware, Maryland, and the District of Columbia) will be held in Paterson, New Jersey, on Saturday, April 4, 1959. There is no charge. Advance registration is requested. Applications should be addressed to R. R. Goldenberg, M.D., St. Joseph's Hospital, Paterson, New Jersey. The following program has been planned:

Surgical Approaches to the Hip Joint: E. B. Kaplan, M.D.;
Bone Tumors. Correlation of Clinical Findings and Roentgenographic Findings with Pathologic Findings: H. L. Jaffe, M.D.;
The Surgery of Flexor Tendons of the Hand: J. W. Littler, M.D.;
Surgical Approaches to the Shoulder Joint: E. B. Kaplan, M.D.;
Differential Diagnosis of the Essentially Fibrous Lesions of Bone: H. L. Jaffe, M.D.;
Experiences with Replacement Hip Prosthesis in Arthritis and Ununited Fractures of the Neck of the Femur: F. R. Thompson, M.D.

The Committee on Scientific Investigation of The American Academy of Orthopaedic Surgeons announces that all manuscripts to be entered for the **Kappa Delta Award,** which is presented annually for the outstanding scientific contribution in the field of orthopaedic surgery and which carries an honorarium of $1,000, should be submitted by July 1, 1959. The manuscript should be forwarded to the Chairman of the Committee: Dr. Frank E. Stinchfield, Columbia-Presbyterian Medical Center, 180 Fort Washington Avenue, New York 32, N. Y.

The winner of the Award will be asked to present the paper before the Annual Meeting of The American Academy of Orthopaedic Surgeons in January 1960. It is, therefore, suggested that the manuscripts be submitted as early as possible so that the utmost care may be given in evaluating each contribution.

The Eighth Congress of the **Pan-Pacific Surgical Association** will be held in Honolulu, Hawaii, September 28 through October 5, 1960. All members of the profession are cordially invited to attend and are urged to make arrangements as soon as possible if they wish to be assured of adequate facilities. An outstanding scientific program by leading surgeons promises to be of interest to all doctors. Nine surgical specialty sections will hold meetings simultaneously. Further information and brochures may be obtained by writing to Dr. F. J. Pinkerton, Director General of the Pan-Pacific Surgical Association, Suite 230, Alexander Young Building, Honolulu 13, Hawaii.

Gordon Research Conference on Bones and Teeth
July 13 through July 17, 1959

The dates of the 1959 Gordon Research Conference on Bones and Teeth have been changed by one week from those originally chosen in order to avoid conflict with the International Congress of Pediatrics which will be held in Montreal, July 19 through 25.

The program is now being organized and the general plan has been established. Discussions centered around each of the four major topics will take place over an evening and the following morning session. Thus a topic will be introduced at an evening session and it will then be discussed to the limit desired by the Conference members at the same session. Discussions of the same topic will be continued the following morning on a more-or-less free-for-all basis. The short communications will be presented at the first session (Monday morning) and in this way the Conference members will have ample opportunity to discuss in private conversation the work of the individual contributors.

The tentative program as it has been arranged by the Sessions Chairman is:

Monday Morning: *Chairman,* Dr. Felix Bronner. Short Communications.
Monday Evening and Tuesday Morning: *Chairman,* Dr. Jonathan Cohen. Bone as a Mechanical Tissue. Contributors: G. H. Bell, F. Gaynor Evans, M. G. Harding, W. F. Dempster, and C. D. Martz.
Tuesday Evening and Wednesday Morning: *Chairman,* Dr. H. C. Hodge. Fluoride Metabolism. Contributors: D. A. Greenwood, Yngve Ericsson, Paul Phillips, Edward Largent, Frank McClure, C. S. Hobbs, Leon Singer, and Curtis Carlson.
Wednesday Evening and Thursday Morning: *Chairman,* Dr. D. Dziewiatkowski. New Developments in Methodology in the Study of Calcified Tissues. Contributors: Diego Carlstrom, Richard Greulich, Harold Schaer, and J. T. Irving.
Thursday Evening and Friday Morning: *Chairman,* Dr. Franklin C. McLean. Pathological Physiology of Bone and Calcium Metabolism.

Book Reviews

COLD INJURY, GROUND TYPE (The Medical Department, United States Army, In World War II). Col. Tom F. Whayne, M.C., U.S.A. (Ret.), and Michael E. DeBakey, M.D. Washington, Office of the Surgeon General, Department of the Army, 1958. $6.25.

Prolonged exposure of the feet to a wet environment of from 61 to 68 degrees Fahrenheit, or lower, will result in progressively severe tissue damage which will be aggravated by further limitation of the circulation by passive dependency or constricting clothing. Where this environment is provided by a wet shoe and sock on a soldier the injury is called trench foot or "cold injury, ground type." This injury can be satisfactorily prevented in the military by frequent, regular foot care with emphasis on dry socks, and by the use of adequate, protective footgear.

The first half of this book is a minutely detailed history of the abysmal failure of the entire United States Armed Forces in World War II to appreciate the lessons of previous wars regarding trench foot, the resultant widespread chiropodial catastrophe and the agonizing inertia of a large organization in correcting the error. This is a uniquely American failure since both our allies and enemies were well equipped and indoctrinated to meet the problem. American troops had ten times the casualty rate from trench foot encountered by the British and Canadian troops fighting in the same area under the same conditions.

Since this thorough historical treatise deals with the problem of cold injury theater by theater and campaign by campaign throughout the entire conflict, and must necessarily describe the tactical situation in each instance, this portion of the work might be entitled "A History of World War II Through A Wet Sock." Presented thus, boldly and without consideration of American triumphs and successes in other aspects of the war effort, this slanted history should give another sputnik-like blow to the American sense of superiority. The fiasco cannot be blamed on one individual practice or service. Although the military blamed inadequate discipline, and Congress with the American mother blamed inadequate shoes, it was a total and general American lapse. Foot discipline was certainly of primary importance, and the United States contrasted sharply with other countries in awarding the Purple Heart for trench foot while other armies tended to consider the lesion a self-inflicted injury punishable by court-martial.

Because of its accurate and detailed documentation this historical section makes entertaining reading for one familiar with the personality clashes and frustrations intrinsic in getting something done in a huge organization like the army.

The second half of the book is devoted to the medical aspects of cold injury and contains chapters on pathogenesis and pathological process, clinical picture and diagnosis, therapy, epidemiology, and prevention and control. The section on pathogenesis and pathological process is excellent. Other sections are fully documented, complete accounts of the World War II experience in the United States Army but appear a little prolix and disorganized if one tries to read them like a medical textbook. The discussions of therapy particularly are rather tough sledding, because of the volume of material one must scan to cover a sought after point.

The book, however, does not attempt to be a medical text but a documentary history of the cold injury problem in World War II. It generously surpasses this ideal, is far from boring, and cannot help but leave the reader a better physician.

Robert S. Shaw, M.D.

ORTHOPEDIC SURGERY IN THE MEDITERRANEAN THEATER OF OPERATIONS (Surgery in World War II). Col. Oscar P. Hampton, Jr. Washington, Office of the Surgeon General, Department of the Army, 1957. $4.00.

This report on orthopaedic surgery in the Mediterranean Theater of Operations has eleven chapters with ninety-six illustrations and thirty-six tables.

The first two chapters deal with administrative considerations, the difficulties involved in developing the consultant system, and problems of medical personnel and hospital administration over a large area.

A short chapter on splinting in the combat zone and classification of military splinting as well as emergency splinting and transportation is well presented. The illustrations of apparatus and various types of splints and plaster casts are good, pointing out the necessity of avoiding wide abduction hip spicas or abnormal abduction position of the shoulder spicas so that the ordinary patient can be transported in a narrow stretcher or in an ambulance.

The management of compound battle fractures is thoroughly covered with a great deal of detail devoted to the concept of adequate débridement and delayed primary closure. There is a thorough discussion of the mechanics of carrying out, in an active battle zone, a large program of delayed primary closure a few days to a week after the original débridement.

The success of the program of delayed primary closures is emphasized. A great deal of credit is given to adequate débridement, replacement of blood, and antibiotic therapy. The

application of these principles changed the entire picture of the management of the open wound. It was proved that delayed primary closure can be done on a very large scale, even in open fractures, provided adequate débridement had been done primarily, blood replacement carried out, and antibiotic therapy, chiefly penicillin, initiated.

The timing and preparation of initial surgery is carefully discussed in relation to a military situation. In this situation medical care is planned and given by different surgeons at different times and in different places. The orientation of the medical personnel to the problems involved was followed through so that surgical care was finally a continuing process even though not carried out by the same surgeon.

The evacuation of the injured from the combat zone to an area where secondary closure may be accomplished accounted for the four to seven-day staging of secondary closures. In those wounds that did break down after delayed primary closure, it was often possible to show that there had been inadequate débridement at initial surgery and that the enclosed dead spaces were either under too much tension or that further blood clots developed beneath the closures.

The use of subcutaneous plates and screws on the tibia were generally avoided in open fractures. Internal fixation was usually through a second incision with adequate covering of the metal with more normal tissue. Open fixation of the tibia, for instance, with a plate would often lead to severe sequestration; this was not generally true if wire fixation or screws were used. Intramedullary fixation was not generally available in this campaign.

The débridement of joints was similar to any other débridement and surgery was specifically directed toward getting the synovial membrane closed. This could not often be done primarily but could be done at the delayed primary closure. The use of primary skin grafts at delayed primary closure was encouraged and carried out successfully. Wide excision, the usual procedure of French and German surgeons in the treatment of infected joints, was not carried out by Americans.

A section dealing with orthopaedic injuries not related to combat is included.

The problems of all battle casualties are presented in this book which also includes a comprehensive review of experiences with amputations and the indications and sites of amputations in open fractures.

Otto E. Aufranc, M.D.

PROGRESS IN ARTHRITIS. Edited by John H. Talbott, M.D., and L. Maxwell Lockie, M.D. New York, Grune and Stratton, 1958. $12.50.

This book is a collection of papers by well known investigators and teachers in the field of rheumatic diseases. Some of the authors are authorities on their subject and others have compiled the available material in the literature concerning their assignment. This latter procedure has not detracted from the usefulness of the symposium. Some sections on subjects of real significance in the field of rheumatic disease seem unnecessarily short. Other sections discuss rather special aspects of rheumatic disease exhaustively.

Fortunately for the general medical reader, the sections on treatment relative to the syndromes discussed are thorough and reasonable. The more exotic subjects are covered in a creditable fashion and I am sure even the most ardent student of rheumatic diseases would find material of real interest in some of the sections. The book is well printed, adequately or profusely illustrated with good photomicrographs of pathological material and the bibliography for each section is either adequate or exhaustive. The book can certainly be strongly recommended to students of rheumatic disease and on the whole the general medical reader will find practical material in it. Certainly, careful perusal of this book will increase his interest in rheumatic conditions and give him up-to-date knowledge.

Theodore B. Bayles, M.D.

DIE THERAPIE DES ANGEBORENNEN KLUMPFUSSES. Prof. Dr. med. Hans Debrunner, Stuttgart, Ferdinand Enke, 1957. DM 40.20.

This book is a very detailed, complete, and well illustrated treatise on club-foot. The author, Professor of Orthopaedic Surgery at the University of Basel, analyzes all aspects of the deformity with an authority apparently based on wide experience.

Although mainly concerned with the treatment of the club-foot, the etiology and pathogenesis is fully discussed. A very interesting chapter is devoted to the abnormalities of the soft parts, muscles and ligaments, the importance of which in the pathology of the club-foot has only been acknowledged in recent years.

His own treatment in early cases follows the principles of the German school of the last decades, but he also appraises the methods of Denis Browne and the wedged-plaster-cast method advocated by Kite, which is described in detail. We all agree that treatment should begin as soon after birth as is practicable. He cites J. H. Kite: "The earlier congenital deformities are corrected the easier they are to correct and the better the chance for correction to be retained." In difficult and recurrent cases, surgical correction is recommended. These procedures are many and should be carefully selected according to the requirements of each indi-

vidual foot. Operations to be considered are Achilles-tendon lengthening, tendon transfer, medial soft-tissue release, posterior soft-tissue release, and, in the older resistant cases, tarsal arthrodesis.

The book is of value to the medical student and to the orthopaedic resident who read German. The clarity of the illustrations and the beautiful printing are impressive.

Julius Hass, M.D.

HEMOPHILIA AND HEMOPHILIOID DISEASES. INTERNATIONAL SYMPOSIUM. Kenneth M. Bringhous, Editor. Chapel Hill, University of North Carolina Press, 1957. $7.50.

This book contains a group of papers presented at a symposium on hemophilia sponsored by the National Hemophilia Foundation at the Ambassador Hotel in New York, August 24 to 25, 1956. The papers cover the many problems of this complex and interesting disease group and bring one up to date on the great amount of available information on the related difficult problems of blood-clotting. Various types of hemophilioid disease are presented with as much as is understood of their etiology and clinical pathology.

A chapter on genetics explains the present-day understanding of that interesting and baffling phase of hemophilia and points out the similar features of other hemophilioid diseases as well.

A part of the book which will be of interest to most orthopaedic surgeons is devoted to the hemophilic arthropathy. A section on pathology is presented with excellent colored illustrations of joints from hemophilic dogs. Also, papers from some of the larger clinics discuss the management of the hemophiliac with arthropathy.

While the book is by no means a primer on hemophilia, it does contain valuable and up-to-date discussions of the many phases of this most difficult disease. It is well worth a place in the library of the orthopaedic surgeon.

Ralph K. Ghormley, M.D.

STUDY OF METALLIC IMPLANTS

The Committee on Bio-Mechanics of The American Academy of Orthopaedic Surgeons is endeavoring to accumulate data on the behavior of implants used in bone surgery, together with accurate descriptions of tissue reactions about such implants. The Committee is extremely anxious for the pathologists to cooperate in such studies. It seems logical that all implants removed from the body together with surrounding tissue should be studied and described by the hospital pathologist in the same manner other material is submitted to the laboratory for study. Since re-use of such implants makes them more liable to failure because of defects which develop from fatigue or normal use, accumulation of used implants by the pathologist would also prevent such re-use.

Since improvement of materials, design, and the application of all implants is of interest to all surgeons, especially the orthopaedists, accumulation of data concerning failures of devices is imperative. Such failing devices discovered at surgery or in the laboratory should be studied by metallurgists and stress analysts. This further study can be achieved by accumulating such specimens for study by the Committee on Bio-Mechanics. These specimens consisting of the implant and tissues, should be sent to the Committee on Bio-Mechanics of The American Academy of Orthopaedic Surgeons, 116 South Michigan Avenue, Chicago, Illinois. No identification of patient or institution is desirable or permissible; however, when possible the time elapsed between insertion and failure together with x-rays of such devices should be included to assist in this study.

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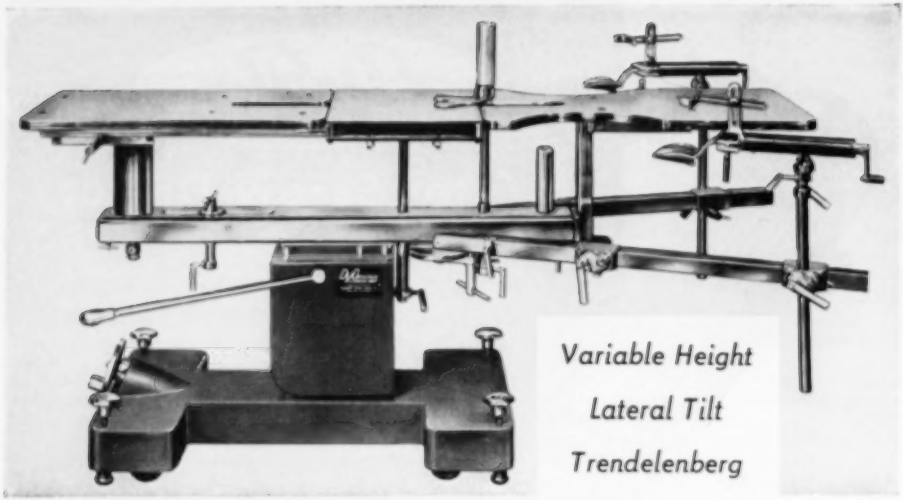

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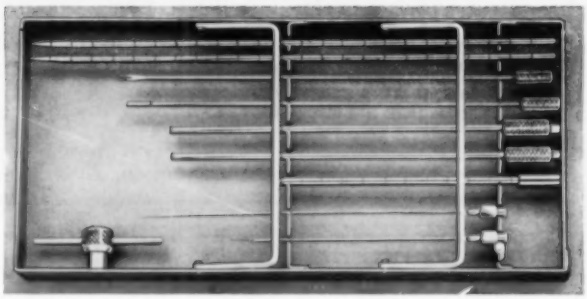

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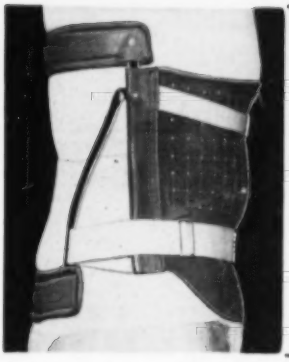

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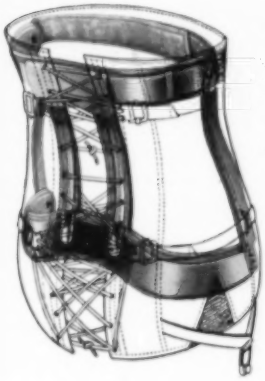

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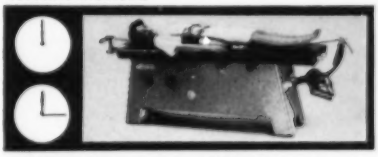

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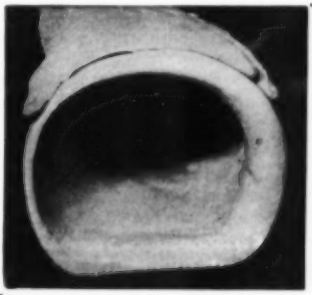

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